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SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

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Some Special Photographic Effects Used in Motion-Picture Production

By RAY KELLOGG
and L. B. ABBOTT

This paper describes four types of special photographic effects used in motion-picture production: (a) the matte shot combines live action and a painting into one scene; (b) the composite matte shot employs the matte shot plus the combination of two or more action scenes; (c) the glass shot is a method of photographing the live action and the painting simultaneously; (d) the traveling matte shot combines foreground action, which has been photographed against a monochromatic backing, with any desired background.

Before any type of motion-picture composite photography may be successfully attempted, the requirements of the equipment and film to be used must be considered.

The location of the image relative to the perforation hole must be repeated from frame to frame within a maximum tolerance of 0.001 in. This means that the camera and printers used in assembling the composite must have register pins which accurately fit the perforations of the films used, and that these films must be uniformly perforated. Failure to meet these requirements will cause the parts of the completed composite to move against themselves and disclose the fact that the scene is not a unit but composed of two or more parts.

We shall discuss the four types of special photographic effects that are most generally used in current productions.

Stationary-Matte Shot

This type of shot derives its name from a matting process that is presently used during the duplicating steps. It has two aims: (1) to change locale (i.e., to put a foreground set with action into a background of another part of the world); and (2) economy: obviously it is much cheaper to paint a picture of the upper floors of a building than it is to build them. This is also true of huge vaulted and elaborate ceilings, such as those of a cathedral, etc. Transportation, housing and other costs are saved by making the shot in the studio, even if such a building is obtainable elsewhere.

Before duplicating stock was available it was necessary to block out or matte out certain portions of a scene so that it would be possible to double expose on the same negative a different mountain, the upper stories of a building, clouds, etc. This was done by cutting a matte of the desired shape and placing it in front of the camera. If a hard-edge matte was needed, it was placed far enough from the camera to be in focus. Conversely, if a soft-edge matte was needed, it was placed in the matte box attached to the camera and therefore out of focus.

The scene would then be shot with the camera securely tied down. At the end of the scene, 200 additional feet of film would be shot for testing purposes. Using an enlargement from a short piece of the test negative, the artist would add the necessary painting and would black in the area which had not been matted out when the scene was photographed. Using the rest of the undeveloped test piece, the painting would then be balanced for exposure and corrected in other ways until the composite was satisfactory. At this point the painting was added to the original scene on the production film.

Since any mechanical or physical fault during the final stage would ruin the scene, the above method was abandoned as soon as good duplicating stocks were available, and the mattes are now made after the scene is shot and used during the duplicating stage. This method is

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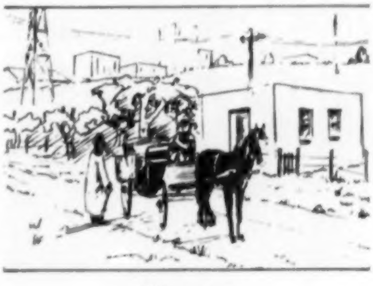


Figure 1-A

Figure 1-B

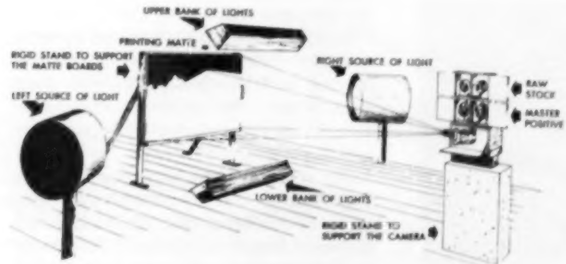


Figure 1-C

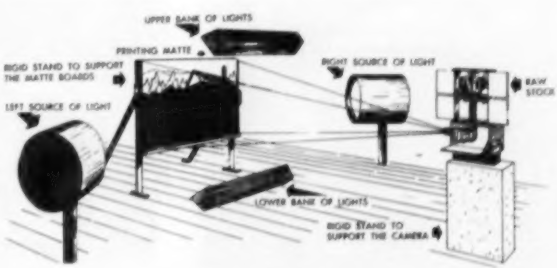


Figure 1-D

more flexible and allows for better control.

Figure 1-A depicts a scene which is available and can be made at the studio. Figure 1-B shows the completed scene. Note the added roof-tops, removal of oil derricks, etc.

To accomplish this, a master-positive print is made from the negative. A master-positive print differs from a regular projection print in the following manner: (1) the master-print stock has perforation holes which are the same as those of the negative, making it possible to retain good registration. (2) the emulsion of this stock is so designed that when used in conjunction with a specially designed duplicating negative, the resulting duplicate will match the original negative.

Figure 1-C shows the method used in making the duplicate negative of the action portion of the scene. For this the camera is made into a printer by the use of a bipack magazine. The duplicating negative raw stock in the magazine's upper section is passed through the camera movement in back of, and in contact with, the developed master positive of the scene action. The matte board, focused in the aperture by the lens, becomes a printing light source, large enough to afford easy hand control of the intensity of any area. In this instance, the portion of the picture which will be painted in the final matte shot is painted black on the (action) printing matte, so that while printing the action duplicate negative this area of the negative will remain unexposed.

Figure 1-D shows how the painting is added to the exposed but undeveloped duplicate negative. The painting is substituted for the matte board and is painted black in the area occupied by the action. The printer is made a camera by eliminating the action master positive. The painting is added to the action duplicate negative in the area which was left unexposed by the black of the matte board, and the shot is complete. When the completed shot is viewed, should changes be desired, it is only necessary to make another duplicate negative.

Composite-Matte Shots

The same methods of matting and duplicating that are used in straight matte shots are used for this type of shot. The main difference is that in this case two or more action sections will be combined with a painting.

This type of shot is almost invariably used when huge crowds of people are needed. By using 200 extras and moving them from area to area, it is possible to build a crowd of 2000. Since each extra, with wardrobe and makeup, plus additional expenses, costs about $35.00 a day on a costume picture, a tremendous saving can be made. The latitude of this type of shot is almost limitless, as long as the camera does not move.

Figure 2-A illustrates a composite-matte shot made with four parts. To compose such a picture, it is first necessary to make a careful drawing to show the overall effect. This drawing must also establish the proper perspective for all the parts, plus the relative scale of objects and people.

In Fig. 2-B distance and perspective have been established. The figure on the porch is photographed. He can move about as long as he does not go beyond the proposed matte line.

In Fig. 2-C, with distance and perspective established, the woman is properly located and photographed. The same light source and angle of light must be generally maintained for all the composite parts.

An area of water is photographed in Fig. 2-D. If it is miniature water, care must be taken to get the surface disturbance large enough in the foreground to diminish properly in the background. Rough forms can be erected to cast

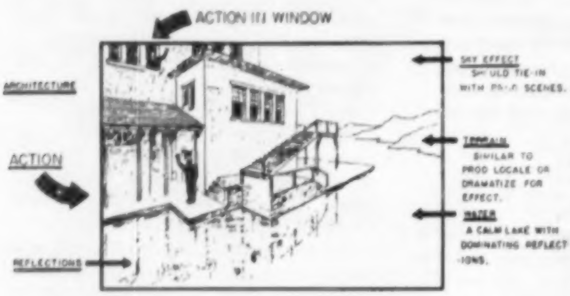


Fig. 2-A. Proposed Composite Picture from art director's sketch or suggestion from Special-Photo Dept. based on available material.

Figure 2-B

Figure 2-C

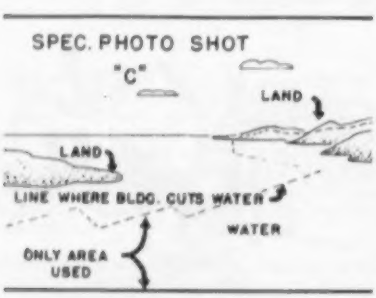


Figure 2-D

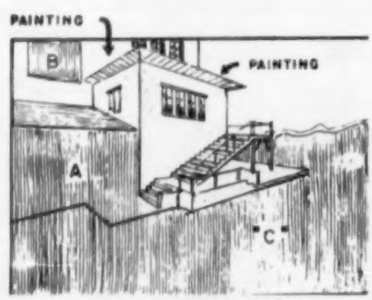


Figure 2-E

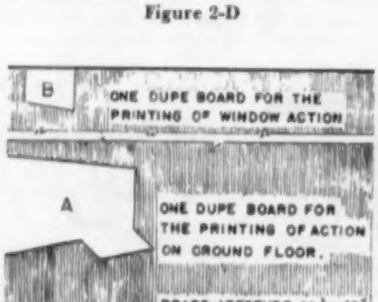


Figure 2-F

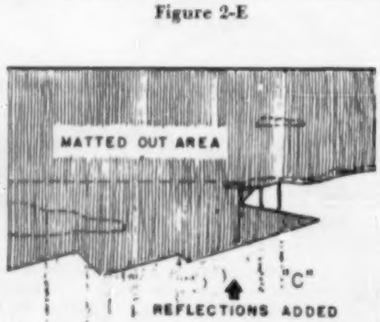


Figure 2-G

proper reflections, or they can be dodged in or, where highlights appear, be double exposed in later.

Figure 2-E shows a painting of the building. This painting must be drawn in true perspective, carrying out the perspective lines to their proper vanishing points. The color and shading must match exactly with the action composite parts. The areas where the people and water will fall in the composite is blacked out so that there will be no exposure in them.

Figure 2-F shows a perfect reverse matte from that in Fig. 2-E. That is, the blacked-out areas are now white, and they become a controlled printing light. With these mattes the man on the porch and the girl in the window are duplicated, using a master print on a duplicate negative.

In Fig. 2-G, in the same manner as in Fig. 2-F, the water area is white and the rest is matted out. After the water is duped in, the dupe negative is run through the camera again and, with the use of a printing matte which is all black except for painted reflections from the building, the highlight reflections are double exposed.

The Traveling-Matte Shot

This process provides a means by which foreground action photographed against a monochromatic background may be combined with any desired background which has been or will be photographed.

The product received from the traveling matte is, in a broad sense, identical to that of the background transparency process. The advantages of the traveling matte over background transparency are: better definition in the background, unlimited foreground scale, and the facility of balancing the background and foreground for both color and density in the duplicating stage.

The term traveling matte means a matte which is changing in each successive frame following the action of the scene. There are a great many ways of obtaining these mattes for both color and black-and-white pictures. One method, used quite widely for many years, was to project each frame of the foreground action enlarged to a scale sufficient to allow hand drawing and then to make a silhouette drawing of each frame. Such a method was obviously tedious and expensive, and has been used mostly for combining miniature and live action in short scenes depicting disasters, such as fires, floods, earthquakes, etc. It has been applied only in cases where the scale of the desired scene exceeded that obtainable by the background transparency process, or where it has been necessary for the people in the scene to be covered or obliterated by some falling or advancing part of the background.

The method to be outlined here entails no handwork, with the exception of those instances in which the background must progress or cover the foreground. Credit for the method presently in use should be given to the British and American Technicolor Corporations; Irving Ries, M-G-M Studio; and Larry Butler, Columbia Pictures.

The problem confronted in making a matte without handwork is to be able to separate photographically the whites and blacks of the foreground from those of the background. This is accomplished in color photography in the following manner.

Figure 3-A shows the foreground photographed against a blue backing. A blue backing is chosen because it will expose the blue-sensitive layer of, for example, an integral negative film, and it will not expose the red-sensitive layer. This selectivity of color sensitivity is the key to the process. Any color which will expose one of the three — red, blue or green — layers without exposing one of the others may be used for the backing. Blue is favored because, when lighting the action, face quality is more easily judged than it would be against yellow or green or red; also, should there be any matte fringing in the final scene the blue edge-effect is more apt to be harmonious with the sky or water that often constitutes the background than would a red or green fringe.

Figure 3-B is the black-and-white separation positive from the blue-sensitive color negative. The darks of the foreground are well separated from the light background.

Figure 3-C is a dupe negative from the black-and-white separation positive of the red-sensitive color negative. The lighter areas of the foreground, which are now dense because this is a negative image, are well separated from the clear background.

Figure 3-D represents a combined print of Figs. 3-B and 3-C on one film. It is seen that there is now density in both the white and black areas of the foreground, causing a complete silhouette against the clear background.

Figure 3-E is a print from Fig. 3-D, which yields a clear foreground with an opaque background.

Figure 3-F represents a background scene viewed through the silhouette foreground matte.

Figure 3-A

Figure 3-B

Figure 3-C

Figure 3-D

Figure 3-E

Figure 3-F

Figure 3-G

Figure 3-H

Figure 3-G represents the foreground viewed through the clear-area foreground matte. Since the blacks of Figs. 3-F and 3-G represent no exposure in a negative, it is readily seen that each part may be exposed separately on the same negative, producing the final composite (Fig. 3-H).

This explanation of the traveling-matte process has been condensed as much as possible to make its function most easily understood. In doing so, the physical and mechanical problems encountered have not been mentioned. Unfortunately, these factors present some sizable hazards, and to avoid misunderstanding, a few of the requisites should be discussed.

No color approaching that of the background may be used in the foreground, nor may translucent materials such as smoke, a glass of water or a fine-mesh veil be used. Should any of these be attempted, the results will be disheartening. In the case of the foreground color too closely approaching that of the background, it will join the background in the mattes, and the background will appear through the foreground. As an example, if the ingenue uses blue eye-shadow, she will have holes in her head instead of eyes, or if she wears a white veil through the rest of the picture, in these shots it will be blue.

The mechanical needs are an optical printer with excellent registration in the movements and a lens stage capable of repeatable moves in the order of 0.0001 in. The processer must have a thorough understanding of the function of image spread in the matte films, as this is the means used to produce opposite mattes which fit one to the other.

Although the hazards of making a traveling matte may suggest that the traveling matte process is impractical, the fact is that its advantages in motion-picture production are so great that it is being used more and more by the industry.

Glass Shots

This is another method of doing the same thing as is done in a matte shot, i.e., adding a painting which may appear to be in front or in back of the foreground set. In actuality, the painting is always closer to the camera than any part of the set. The glass shot has one advantage over the matte shot, namely the ability to pan or tilt the camera while shooting. This is possible because we are shooting a painted glass and a scene simultaneously. It should be noted that a glass shot is completed in one operation, involving no secondary photographic operations.

Lighting of the painted glass must be controlled to allow for light changes on exteriors. It is always necessary to have enough light to maintain a level high enough to carry focus on the painted glass and action beyond it.

In order either to tilt or pan, it is necessary to have the lens centered over the node. This will hold the position of the painted section of the glass constant with respect to the real set it is matched to and avoid parallax.

Figure 4-A shows the relative positions of the camera, the glass, its painted and clear areas, the action and the face of the set.

Figure 4-B shows the panning area, the method of hiding the glass frames, the painted area, the clear glass and the matte line where painting and set join. Through the clear area, any desired action can take place, as long as it is below the matte line. Figure 4-C is a ground plan of the setup. Figure 4-D shows the nodal point head and how the lens is centered over the vertical and horizontal axis.

Remarks

The four methods of special photography which have been described here can all be used for present-day color productions. As delineated in this paper, three of them describe the technique as applied to black-and-white production. The approach for color production for these three techniques — i.e., stationary-matte shots, composite-matte shots, and glass shots — would be straightforward.

The fourth technique — i.e., traveling mattes — can be used as described in this paper only for motion-picture production in color. This process will not work with black-and-white production because it depends on the selectivity of color for its very operation — the preparation of the mattes and subsequent masking of unwanted scene area.

There are at least three other well-known techniques for producing traveling mattes in black-and-white motion-picture production. For the sake of simplicity, we will call these the Dunning process, the density-separation process, and the process using a prism camera and a colored background. The Dunning process consists of shooting the background scene, making a print of this, bleaching away the silver, then dyeing the gelatin image yellow and using this yellow "key" in the camera bipack fashion against the panchromatic raw stock which will be used for the final composite negative. The foreground action is lighted with yellow light against a blue background. The foreground action may be photographed through the yellow "key" because the light reaching the camera from this yellow-lighted foreground passes through the "key" just as if it were not there. The blue-lighted background screen serves as a light source which is modulated by the yellow "key" and produces an image on the panchromatic film by virtue of the different degrees of density of the yellow "key" to blue light. In this way, a single shot is obtained, which at one stroke shows the foreground action against a background scene.

The second method of making mattes for black-and-white production — the density-separation method — consists of photographing foreground action against a totally black background, thus obtaining a negative film with varying degrees of density for the foreground action and with no density for the background. The foreground action must be brightly lighted and very fully exposed in order to get good separation. A minimum of light must be allowed to fall on the black background. By subsequent duplicating operations it is possible to make a high-contrast matte of this foreground action

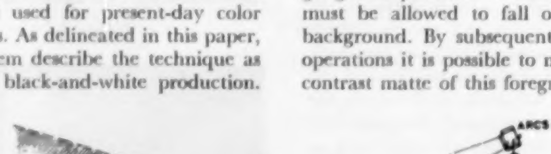


Figure 4-A

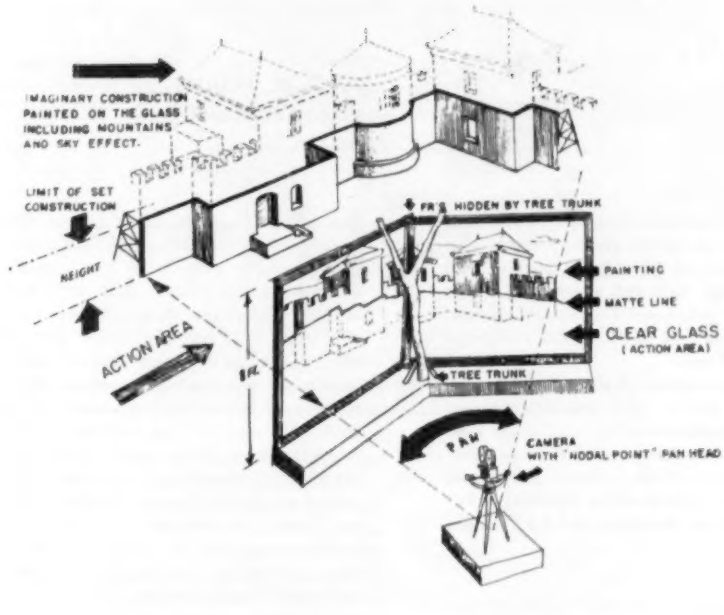


Figure 4-B

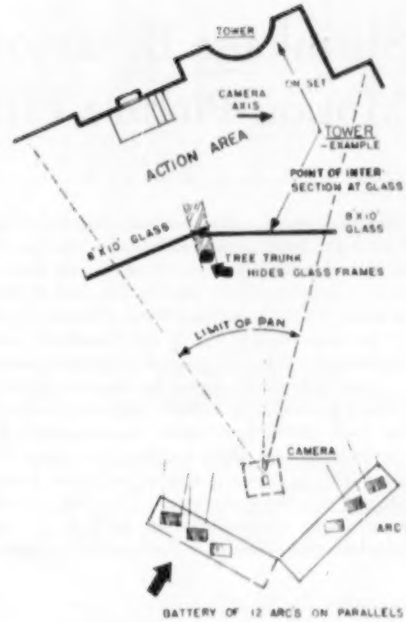


Figure 4-C

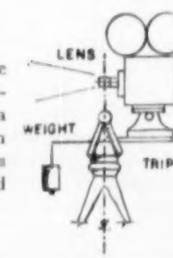
and, by making negative and positive mattes, to combine the independently shot background action and the foreground which has been shot against the black background.

The third and best method employs the use of a specially designed camera which uses a sputtered-surface block prism identical to that used in the Technicolor three-strip cameras. This prism makes possible simultaneous exposure of two films, each of which will have good definition. Cameras of this type are now in use in England for the production of black-and-white traveling mattes in the following method. The foreground action is photographed against a blue backing. The same backing used in the color process is adequate. The foreground action is lighted with yellow light and recorded through the prism and a yellow filter on panchromatic negative. The mirror reflection of the prism is recorded on blue-sensitive film and is obviously a matte of the foreground action.

Albert Tondreau of the Warner Bros. Studios has achieved very satisfactory results using a prism camera and lighting a translucent screen from the back with ultraviolet light. The matte image is recorded on blue-sensitive film and the foreground action may be lighted in the normal manner. This system requires the use of a Wratten 2B filter on the foreground action to eliminate the ultraviolet light from the foreground record and the use of a Corning filter which will pass only ultraviolet light to the matte film.

These split-beam systems have a great advantage over the present color method, in that the backing becomes black behind the foreground action and therefore is most easily matted in the combining process. An interesting thought for the future is that of applying the split-beam system to produce traveling mattes in color. The hindering factors at present are that the blue-sensitive films lose their sensitivity very rapidly below 400 mμ, and there is no ultraviolet illuminating source strong enough to expose the matte film when a filter passing only the wave lengths below 400 must be used.

Fig. 4-D. Note special pan-head tripod whereby camera lens is centered on nodal point of lens and that of tripod pivot.



There is no doubt that the impetus provided by the whole motion-picture industry changing to color production for wide-screen display will soon produce new materials and machines to simplify many of the problems mentioned in this paper. Undoubtedly many readers of this paper who are not principally concerned with photographic effects will have many constructive criticisms and advanced ideas. The photoeffects personnel of the industry will welcome such interest.

Shrinkage Behavior of Motion-Picture Film

By C. R. FORDYCE, J. M. CALHOUN and E. E. MOYER

Shrinkage characteristics of both 35mm and 16mm films manufactured by Eastman Kodak Co. have been evaluated by laboratory measurements and by examination of film in commercial use. Professional 35mm triacetate films (both positive and earlier negative stock) show a low rate of shrinkage with age, reaching a range of about 0.3% in the lengthwise direction in three years and a maximum amount of not more than 0.6% in the lengthwise direction and 0.7% in the widthwise direction on the average over very long periods of time.

An improved support for negative films is now being produced which provides a maximum aging shrinkage of not more than 0.3%. This base is being used for both 35mm and 16mm negative stock for black-and-white and color film. 16mm black-and-white positive films show essentially the same shrinkage characteristics as 35mm positive products. Kodachrome 16mm acetate propionate films of current manufacture have low shrinkage characteristics, reaching maximum values of approximately 0.3% in the lengthwise direction and 0.4% in the widthwise direction over long periods of time.

ONE of the important properties of motion-picture film is its susceptibility to shrinkage with age and to change of size with varying relative humidity and temperature. In many cases the steadiness of a projected image, or even the photographic quality of a print, is limited because of undesirable dimensional change of either negative or positive film stock in preparation of the picture. Dimensional stability is even more important in certain color processes where perfect registration of several images on one film is required.

It is the lengthwise size change of the film which is particularly critical in making prints from a negative on a continuous printer. On the other hand, the width of projector gates sometimes makes widthwise size changes in the film more important. In registration of color images both lengthwise and widthwise changes must be controlled.

The nature of the various dimensional changes which occur in motion-picture film was described in detail in 1944,[1] but the data given then do not apply accurately to current films. Briefly, these dimensional changes may be classified as *permanent* and *temporary*. The former are caused largely by the loss of residual solvent remaining in the base and, to a lesser extent, by various mechanical effects. The latter are caused by changes in relative humidity or temperature and are reversible.

This paper deals primarily with permanent shrinkage and its purpose is to present as clearly as possible the shrinkage characteristics of current Eastman motion-picture films.

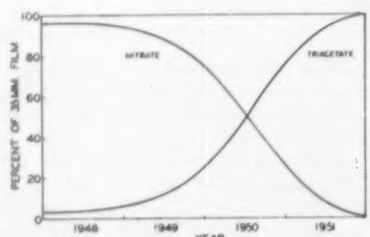


Fig. 1. Rate of replacement of Eastman Nitrate Motion Picture Film by Triacetate Safety Film.

During the past five years most 35mm film products have been converted from cellulose nitrate to cellulose triacetate* film base. Manufacture of 35mm film in the United States by the Eastman Kodak Company since 1948 has been divided between nitrate and triacetate base in proportions shown by the chart of Figure 1. Until the latter part of 1949 quantities of 35mm film on safety base were very small. A rapid transition to triacetate film support occurred in 1950, and since 1951 no cellulose nitrate products have been made. Although the triacetate base film has a rather brief record in terms of years of commercial use, there are now available sufficient performance data to present a fairly clear picture of current and probable future shrinkage behavior.

Positive Film

Most of the measurements made in this study were on release positive film. The physical properties of the triacetate base have been such as to give very nearly the same shrinkage characteristics on all films, however, whether positive stock or negative stock made prior to 1954, and whether color or black-and-white film. All results are based upon measurements on films manufactured by the Eastman Kodak Company, and should be applied to those products only. The shrinkage measurements were made with essentially the same equipment as described by Calhoun[2] in 1947.

The linear shrinkage behavior of strips of triacetate base film exposed to normal inside conditions (78 F and 60% R.H.) is shown in Fig. 2. A slight shrinkage occurs during photographic processing, after which a gradual aging shrinkage occurs, totalling about 0.3% in three years. This is somewhat greater than

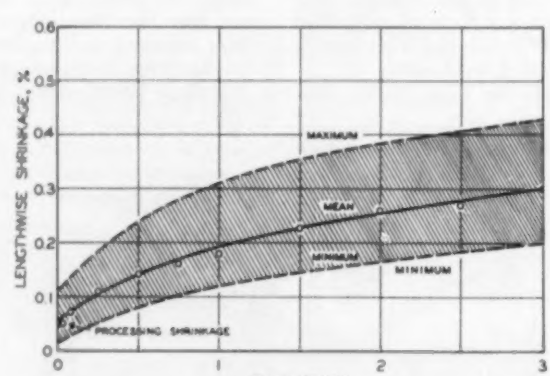


Fig. 2. Rate of shrinkage of processed triacetate 35mm motion-picture positive film at 78 F and 60% R.H. Controlled tests on strips freely exposed to circulating air; all measurements made after reconditioning at 70 F and 50% R.H.

* Actually, a "high acetyl" acetate (42.5 to 44.0% acetyl), not a theoretical triacetate (44.8% acetyl).

Presented on October 22, 1954, at the Society's Convention at Los Angeles, by C. R. Fordyce (who read the paper), J. M. Calhoun and E. E. Moyer, Manufacturing Experiments Div., Eastman Kodak Co., Rochester 4, N.Y.
(This paper was received on October 6, 1954.)

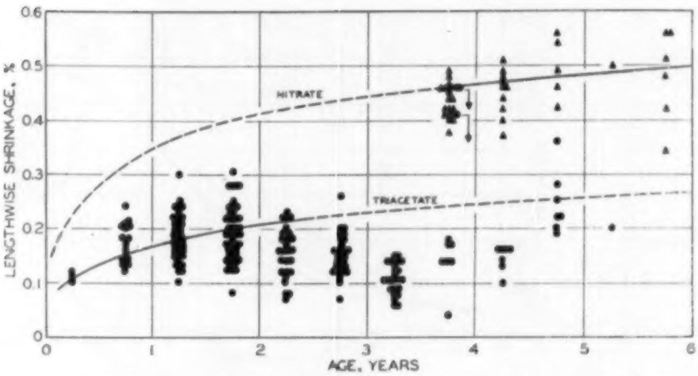


Fig. 3. Shrinkage vs. age for triacetate and nitrate prints scrapped after normal theater use. Measurements made at 70 F and 50% R.H.

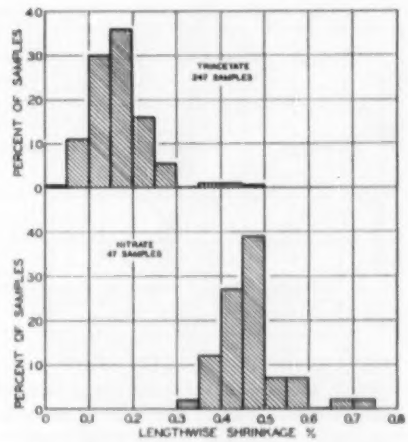


Fig. 4. Frequency distribution of shrinkage of triacetate and nitrate prints scrapped after normal theater use. Measurements made at 70 F and 50% R.H.

would be expected in normal use because shrinkage during storage in rolls would be slower than in freely suspended strips. This is borne out in Fig. 3, which shows the shrinkage rate of films which have been in commercial use. It will be noted in this chart that triacetate films which are three years old show a lower shrinkage than those which are two years old. This arises from the fact that the positive film made more recently has slightly higher shrinkage than the film made earlier because of changes in manufacture necessitated by other requirements such as curl. The curve for triacetate film is drawn to represent the behavior of the current material. For comparison, the shrinkage rate of cellulose nitrate release positive film is included on the same graph. These curves were made from measurements on samples of 247 triacetate and 47 nitrate release prints returned to the factory for scrap recovery after normal theater use. In Fig. 4 is shown a frequency distribution chart of the shrinkage variation of these same 35mm films, all of which have completed their useful print life.

By use of accelerated aging tests it may be demonstrated that there is a much higher potential shrinkage than has been shown in the previous charts. When film was incubated at 90 F and 90% R.H. results given in Fig. 5 were obtained. Strips of film in free access to this atmosphere for three years show a lengthwise shrinkage on the average of about 0.6%. (The range among different samples is generally within 0.5% to 0.7% shrinkage.) The reason for this shrinkage is that there is a certain amount of residual solvent in the film base which slowly finds its way to the surface and escapes over a period of time. The rate of this residual solvent dissipation is accelerated by elevated temperatures, particularly at very high humidity. The amount of shrinkage which takes place in a film is, therefore, proportional to the amount of this solvent which has escaped. In the same manner, the maximum shrinkage which will ultimately take place can be calculated if one knows the residual solvent content of the film.

The relation of total residual solvent content to maximum shrinkage at 90 F and 90% R.H. is given in Fig. 6. This maximum shrinkage at 90 F and 90% R.H. is due almost entirely to solvent loss

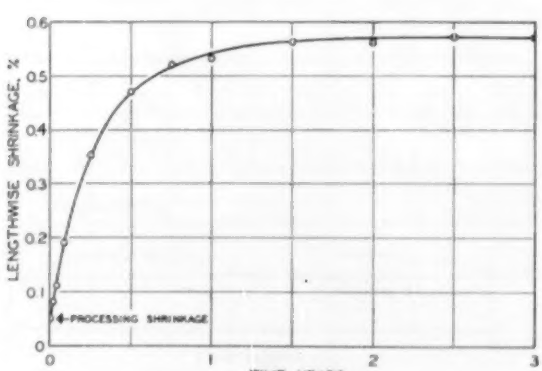


Fig. 5. Average rate of shrinkage of processed triacetate 35mm motion-picture positive film at 90 F and 90% R.H. Controlled tests on strips freely exposed to circulating air; all measurements made after reconditioning at 70 F and 50% R.H.

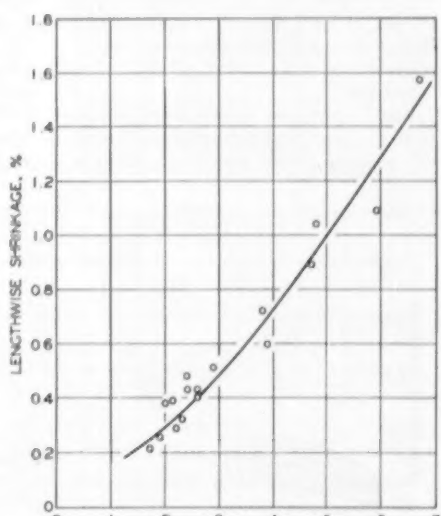


Fig. 6. Correlation between initial residual solvent content of triacetate base and maximum shrinkage of the film at 90 F and 90% R.H. Controlled tests on strips freely exposed to circulating air; shrinkage measurements made after reconditioning at 70 F and 50% R.H.

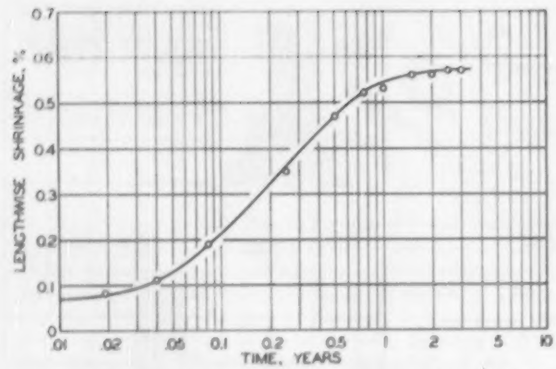


Fig. 7. Average rate of shrinkage of processed triacetate 35mm positive motion-picture film at 90 F and 90% R.H. (logarithmic time scale). Controlled tests on strips freely exposed to circulating air; all measurements made after reconditioning at 70 F and 50% R.H.

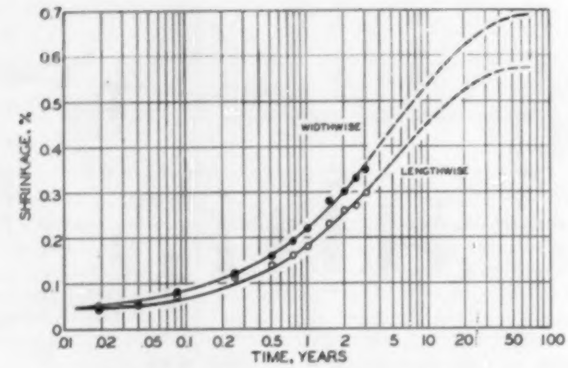


Fig. 8. Average shrinkage rate of processed triacetate 35mm positive motion-picture film at 78 F and 60% R.H. (plotted on a logarithmic time scale for extrapolation). Controlled tests on strips freely exposed to circulating air; all measurements made after reconditioning at 70 F and 50% R.H.

from the base and so represents the maximum potential shrinkage which will occur in longer times at more moderate conditions. It does not mean, of course, that this is the maximum shrinkage which can occur at any temperature, since shrinkage from mechanical causes can be produced if film is heated at more elevated temperatures. Analytical tests have shown that the residual solvent content of triacetate base Eastman Fine Grain Release Positive Film, Type 5302, is in the range of 3.5% to 4.0% at the time of manufacture. The shrinkage of 0.6%, obtained at 90 F and 90% R.H., as shown in Fig. 5, therefore, represents virtually the total shrinkage to be expected over any period of time under normal conditions. This has been confirmed by solvent analyses made on film samples after storage at 90 F and 90% R.H., which show that a negligible amount of solvent remains where the curve of Fig. 5 becomes level.

Based upon rate of shrinkage of film with the time under normal room conditions, over a short period of years, it is possible to predict with some degree of accuracy the probable shrinkage behavior over long periods of time. This can be done by plotting shrinkage against the logarithm of time, which gives a typical S-shaped curve having a middle section which is nearly linear. The data of Fig. 5 for shrinkage at 90 F and 90% R.H. have been replotted in Fig. 7 in this way to illustrate the type of curve obtained. Now we can plot the data for shrinkage at normal conditions, 78 F and 60% R.H., in the same fashion and extrapolate the curve with reasonable assurance, as shown in Fig. 8. From this graph it may be seen that a lengthwise shrinkage of approximately 0.45% is expected after about ten years, after which a very slow shrinkage rate will continue, possibly to as long as 100 years, before the maximum figure of 0.6% is reached. For the purposes of this chart the widthwise shrinkage rate is also included as a separate curve. It will be noticed that the widthwise shrinkage follows closely the lengthwise shrinkage behavior, but is slightly greater in magnitude.

Negative Film

The shrinkage characteristics of negative films must be maintained within a range which will permit good performance in making prints. For optimum quality on continuous printers this requires that the perforation dimensions be at least 0.2% shorter than those of the positive raw stock being used, but not more than about 0.5% shorter. To meet these perforation requirements it is necessary to provide two features in negative film stock. First, the negative films must be manufactured with a perforation pitch of 0.1866, which is 0.2% shorter than the 0.1870 pitch used for positive stock, and second, the aging shrinkage of negative film should not exceed about 0.3% during its useful life. A proposal to manufacture negative film stock in this range of shrinkage performance with cellulose triacetate safety base was reported in 1948.[3] Comparing the experimental data presented at that time with the shrinkage behavior since obtained (same as for positive, Fig. 8) it will be seen that the negative film manufactured until re-

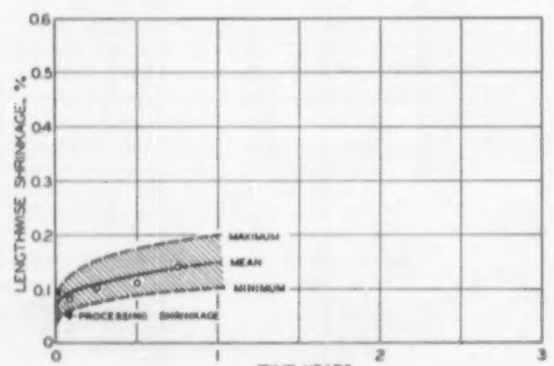


Fig. 9. Rate of shrinkage of processed triacetate 35mm motion-picture negative film at 78 F and 60% R.H. (Lower-shrink support manufactured since June 1954.) Controlled tests on strips freely exposed to circulating air; all measurements made after reconditioning at 70 F and 50% R.H.

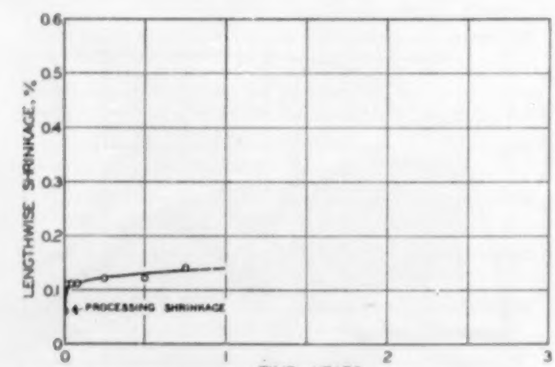


Fig. 10. Average rate of shrinkage of processed triacetate 35mm motion-picture negative film at 90 F and 90% R.H. (Lower-shrink support manufactured since June 1954.) Controlled tests on strips freely exposed to circulating air; all measurements made after reconditioning at 70 F and 50% R.H.

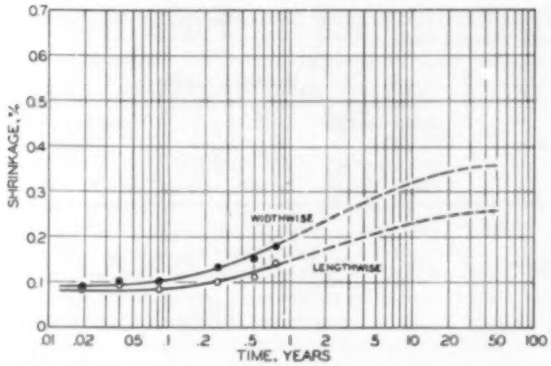


Fig. 11. Average rate of shrinkage of processed triacetate 35mm motion picture negative film at 78 F and 60% R.H. (Lower-shrink support manufactured since June 1954. Data plotted on a logarithmic time scale for extrapolation.) Controlled tests on strips freely exposed to circulating air; all measurements made after reconditioning at 70 F and 50% R.H.

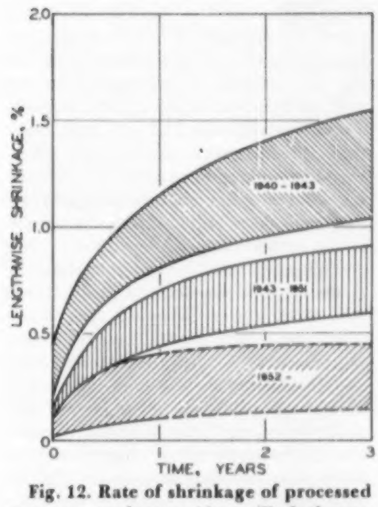


Fig. 12. Rate of shrinkage of processed acetate propionate 16mm Kodachrome films at 70–78 F and 50–60% R.H. Controlled tests on strips freely exposed to circulating air; all measurements made after reconditioning at 70 F and 50% R.H. These data apply to Kodachrome Film, Daylight Type and Type A, and to Kodachrome Duplicating Film, Type 5265; Kodachrome Commercial Film, Type 5268, has been in the lowest shrinkage range since 1948.

cently maintains the desired characteristics for about three years, after which time continued shrinkage at a low rate will give somewhat more than the desired shrinkage, totaling eventually approximately twice the desired amount.

In order to improve this shrinkage behavior, a modified type of negative triacetate film support has been produced since June 1954, using a solvent composition which permits more thorough curing of volatile solvents from the film base. Shrinkage behavior of this material is shown in Fig. 9. The total amount of volatile solvent in this type of film support is about 2%, which should permit an ultimate shrinkage of not more than about 0.3%. The rate of shrinkage at 90 F and 90% R.H., shown in Fig. 10, confirms that this product does not exhibit the higher shrinkage potential of the former support. The anticipated long term shrinkage behavior of present motion-picture negative film base is given in Fig. 11, based on preliminary tests. It is predicted that a lengthwise shrinkage of approximately 0.2% will occur over a period of five years. Because of the total volatile solvent content of 2.0%, it is probable that the lengthwise shrinkage will not exceed a level of approximately 0.3% over longer keeping periods of time. This improved triacetate support is now being used for both black-and-white and color negative films.

Sixteen Millimeter Film

Eastman 16mm black-and-white negative films and black-and-white print film stock manufactured at the present time are on cellulose triacetate base and have shrinkage characteristics similar to those of the 35mm films as described in the previous sections. The average shrinkage of 16mm black-and-white print film stock is generally about 0.1% higher than the average for 35mm film, but still within the range shown in Fig. 2.

Kodachrome films are manufactured on cellulose acetate propionate base. Those products have been subject to changes in manufacture over the past ten years, the modifications being directed toward improved shrinkage characteristics. Figure 12 shows the general shrinkage behavior of Kodachrome films, indicating a higher rate of shrinkage for products manufactured before 1943, a reduced order of shrinkage for films manufactured during the years 1943 to 1951, and a low-shrinkage behavior for current products, manufactured since 1952. These curves apply to Kodachrome Film, Daylight Type and Type A, and to Kodachrome Duplicating Film, Type 5265. Kodachrome Commercial Film,

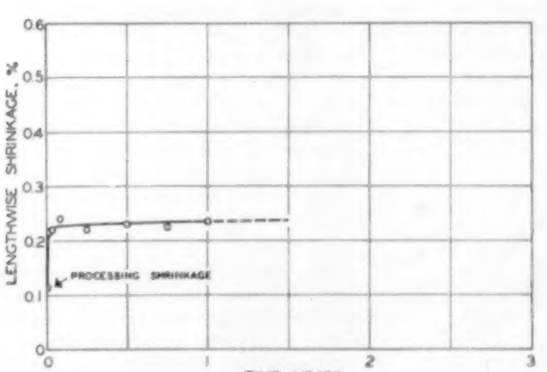


Fig. 13. Average rate of shrinkage of processed acetate propionate 16mm Kodachrome films at 90 F and 90% R.H. (film manufactured since 1952.) Controlled tests on strips freely exposed to circulating air: all measurements made after reconditioning at 70 F and 50% R.H.

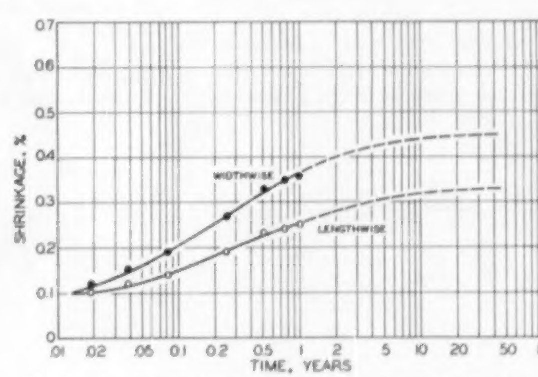


Fig. 14. Average rate of shrinkage of processed acetate propionate 16mm Kodachrome films at 78 F and 60% R.H. (film manufactured since 1952. Data plotted on a logarithmic time scale for extrapolation). Controlled tests on strips freely exposed to circulating air; all measurements made after reconditioning at 70 F and 50% R.H.

Type 5268, since 1948 has been manufactured on support of low-shrinkage behavior, similar to the bottom range of Fig. 12, because of its use as a camera original film from which prints are made. Some Kodachrome film (of types other than Kodachrome Commercial Film) was manufactured on acetate butyrate base and on triacetate base prior to 1953. These products had shrinkage properties in the middle range of Fig. 12.

The accelerated keeping shrinkage of current Kodachrome films at 90 F and 90% R.H. is given in Fig. 13, from which it will be seen that at this humidity and temperature the lengthwise shrinkage rapidly reaches a value slightly in excess of 0.2%, but goes very little beyond that point over a period of one year. Normal keeping behavior of both lengthwise and widthwise directions is given in Fig. 14. It is expected that maximum shrinkage over a long period of years will be in the order of 0.3% lengthwise and 0.4% in the widthwise direction.

Processing Shrinkage and Humidity and Thermal Expansion

Values for the tray processing shrinkage and the humidity and thermal expansion of current Eastman motion-picture films are listed in Table I for completeness. The processing shrinkage is a permanent shrinkage measured after processing and reconditioning at 70 F and 50% R.H. It is generally lower, and sometimes there is even a slight swell when the film is developed on a processing machine, because of a small amount of stretch introduced by the machine tension. The humidity and thermal expansion values are for the temporary or reversible dimensional changes which occur with change in the atmospheric conditions. These values must be added to or subtracted from the permanent shrinkages given above if the film is not in equilibrium with air at the standard conditions of 70 F and 50% R.H.

Table I. Average Processing Shrinkage, Humidity Expansion and Thermal Expansion of Current Eastman Motion Picture Films.

Film	Base	Processing shrinkage, % (Tray development)		Humidity expansion per 10% R.H., % (Range: 20%–70% R.H.)		Thermal expansion per 10 F, (Range 0–100 F)	
		Length	Width	Length	Width	Length	Width
Black-and-White Negative and Eastman Color Negative	Triacetate	.06	.07	.07	.08	.03	.035
Black-and-White Positive and Sound Recording	Triacetate	.05	.05	.05	.06	.03	.035
Eastman Color Print	Triacetate	.07	.08	.06	.07	.03	.035
Kodachrome Films (16mm)	Acetate propionate	.09	.10	.08	.10	.035	.04

References

1. J. M. Calhoun, "The physical properties and dimensional behavior of motion picture film," *Jour. SMPE, 43:* 227–266, Oct. 1944.
2. J. M. Calhoun, "Physical properties and dimensional stability of safety aerographic film," *Photogrammetric Eng., 13:* 163–221, June 1947.
3. C. R. Fordyce, "Improved safety motion picture film support," *Jour. SMPE, 51:* 331–349, Oct. 1948.

Discussion

J. Tritsch (Melrich Instruments, Burbank): I believe at one point Dr. Fordyce referred to a series of tests that were run in actual operation and I believe it was over a period of two to three years in actual theater use. It was my understanding that at a temperature of 78 degrees which was maintained, the film had a minimum of shrinkage resulting. Is that correct?

Dr. Fordyce: There are two sets of data. The first slide was on samples of film that had never seen commercial use. They were developed and then put in a constant temperature room for three years. The film samples in the second slide were never under controlled conditions at all. They were taken from used film collected when they were returned for scrap. We don't have a history of them in any way. There are 247 samples identified as to age of manufacture by the edge markings and are, therefore, random samples of film that have been used commercially.

Mr. Tritsch: Would it be safe to assume that 78 degrees and 60% relative humidity would allow minimum shrinkage, or at least a standard of tolerable shrinkage?

Dr. Fordyce: We used that condition to approximate room conditions and we have expected what we found, that if you expose a strip of film to the air freely, it will shrink a little faster than if kept in a roll and projected occasionally or used some other way; so from these data we feel that a piece of film kept openly exposed at 78 degrees and 60% humidity would shrink faster than the average of products being used in normal use.

Densitometers for Control of Color Motion-Picture Film Processing

By JOHN G. FRAYNE and J. HOWARD JACOBS

The widespread use of negative and positive color films now available to the motion-picture industry has introduced new, more complicated and exacting control requirements in the film-processing laboratories. In step with this trend, two new densitometers have been developed. One instrument is intended to provide precise control of the new color picture processes while the other provides diffuse density measurements of black-and-white, silver sulfide, and silver-image-with-dye sound tracks. The instruments, their application and performance are described.

When the integrating-sphere densitometer was first introduced in the motion-picture industry circa 1940, the requirements, as seen in retrospect, were simple and few in number. It was axiomatic that readings of density, as defined by Hurter and Driffield,[1] should be in uniform agreement among instruments and should be in no way influenced by the design features of the equipment or the judgment of the observer. The spectral sensitivity of the instrument had to be adjusted to that of the eye corrected for the difference between the instrument light source and the standard light source (3000 K), so that visual diffuse density measurements obtained with the physical densitometer would be in agreement with readings carefully made with the visual-type instruments then in current use. It was also recognized that measurements of the printing density of a silver-image negative as seen by the positive film was desirable, although it was not until some time later that this was established as standard practice.[2] Later American Standard Z38.2.5-1946, for diffuse visual density and diffuse printing density, was adopted. Briefly, this specifies that measurements of diffuse visual density shall be obtained by illuminating the sample with nearly collimated light and collecting all of the light emerging from the sample, the spectral sensitivity of the instrument being equivalent to that of the eye corrected for the difference between the instrument light source and the standard light source (3000 K). The measurement of diffuse printing density is similarly specified except that in this case the spectral sensitivity is equivalent to that of the positive film.

The RA-1100 Densitometer, which has been described previously before this Society,[3] has met these requirements over a density range from zero to 3.0 with a reliability of operation and consistency of readings among instruments that has resulted in its general acceptance by the industry as a standard for photographic density measurements. This instrument together with the widely adopted Eastman IIb sensitometer[4] made possible the standardization of the sensitometry of black-and-white motion-picture sound film. It not only facilitated the establishment of essentially uniform picture-and-sound quality in the product of the various studios, but it also made it possible to obtain release prints throughout the world with a uniform standard of quality.

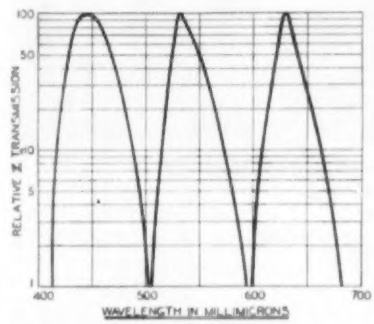


Fig. 1. Spectral characteristics of filters for Ansco Color Negative-Positive Process.

Improvements in the motion-picture art resulted in the need for measurements of higher densities and accordingly the type-A densitometer with a diffuse density range of zero to 4.0 was made available. This was followed by the type-B and later the type-C instrument in which the special aperture for measurement of 100-mil push-pull tracks was eliminated, leaving the 60- and 15-mil apertures available.

Provision for measurement of color-film density was first incorporated in the type-D densitometer which provided an integrating sphere for the measurement of the diffuse density of black-and-white film over a range of zero to 4 and measurement of the diffuse density of color film over the range of zero to 3, using color filters with overlapping spectral characteristics. In this instrument, measurements for the control of various color processes were provided by the use of interchangeable filter wheels, each containing the appropriate set of filters for a particular color process. As an example, a set of color filters, devised in cooperation with representatives of Ansco, was applicable to the Ansco color negative-positive process previously described in the *Journal*.[5] The spectral characteristics of these filters are shown in Fig. 1. Provision was made for the measurement of the specular density of color film over a range of 0 to 4 by introducing a lens and a pair of mirrors within the sphere, so that by means of an external control, the light could be reflected directly onto the photocell. A sketch of this arrangement is shown in Fig. 2. The solid lines show the two mirrors directing the light onto the cathode of the photocell. The broken lines show the mirror assembly withdrawn from the optical path for diffuse-density measurements.

An illuminated surround was placed around the aperture of this instrument to facilitate locating the particular area of the color film to be measured. The use of

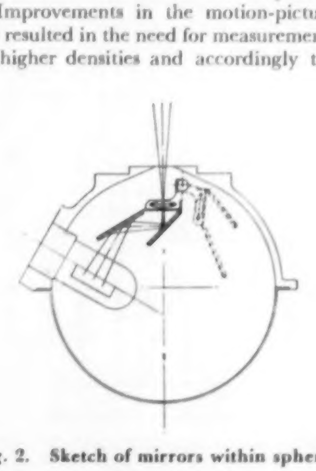


Fig. 2. Sketch of mirrors within sphere.

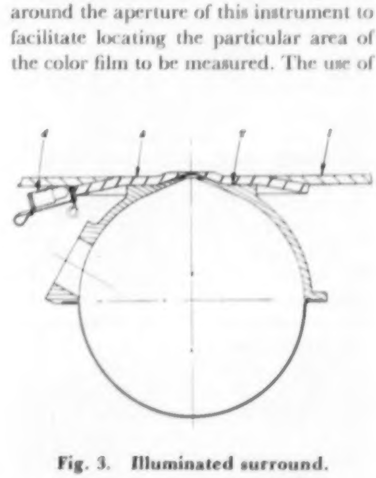


Fig. 3. Illuminated surround.

Presented on October 22, 1954, at the Society's Convention at Los Angeles, by John G. Frayne and J. Howard Jacobs (who read the paper), Hollywood Div., Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.
(This paper was received on October 29, 1954.)

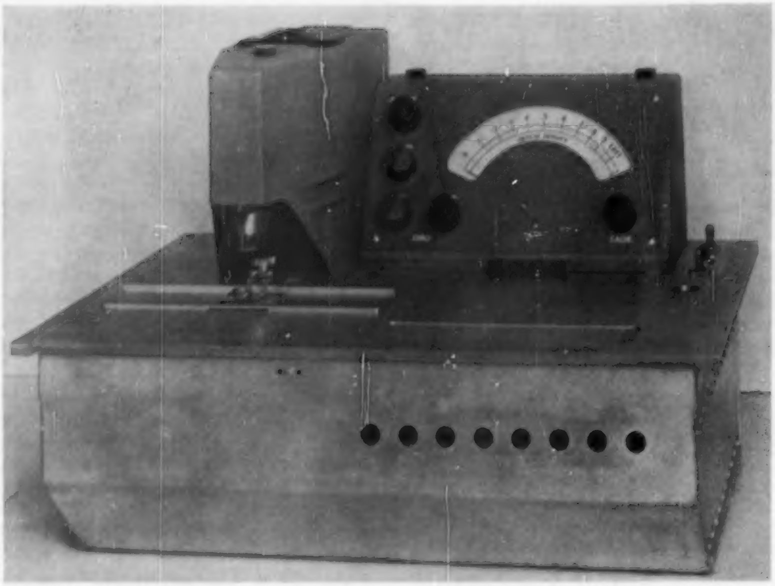


Fig. 4. Front view of RA-1100-E Densitometer.

an illuminated surround was not new in this instrument, nevertheless its introduction presented an interesting problem due to the proximity of the integrating sphere to the film plane. A specially-shaped lucite disk, edge-lighted with six small lamps provided satisfactory illumination. The assembly is shown in Fig. 3. Item 1 shows a section of the instrument panel, and Item 2 is the integrating sphere. The lucite disk, which is edge-lighted, is located between the panel and the sphere and is shown as Item 3. It was specially shaped so that the light internally reflected within the disk provided a suitably illuminated area about the scanning aperture. One of the lamps is shown as Item 4.

Further research into the nature of the color-dye images revealed that the Callier coefficient was sufficiently greater than unity to make the specular-density measurements, supplied by the type-D densitometer, not completely suitable for accurate control of color-film processing. On the other hand, the use of the integrating sphere, while desirable for diffuse-density measurements, was not practical with the low-transmission filters specified by the color-film manufacturers for the measurement of integral color-film densities. This has been discussed by Macleish before the Society.[6]

As an alternate, it was suggested that the sphere be replaced with a 1P42 photocell, mounted so that its active surface is just below the film emulsion. In this position the cell collects nearly all of the light transmitted through the film and the departure of the measurements from diffuse density appears to be insignificant in the control of the current color-film processes. This arrangement has been incorporated in the RA-1100-E Densitometer described below.

The RA-1100-E Densitometer is intended primarily to provide integral-density measurements of picture color negatives and positives and essentially diffuse visual-density and print-density measurements of black-and-white picture film. Figure 4 is a view of the instrument from the operator's position, and without its associated power supply and regulating-voltage transformer which are mounted separately in a convenient place. The head assembly at the left contains the optical system which is shown schematically in Fig. 5. Below the head assembly is an illuminated surround containing a circular aperture 100 mils in diameter. Immediately below the aperture is a 1P42 photocell which collects nearly all of the light transmitted through the aperture. Just above the aperture plate is a film gate which is designed to accommodate 35mm film.

To the right of the head assembly is the meter case containing an easily viewed meter, which has essentially logarithmic response and therefore reads linearly in density. The meter scale reads from zero to 1.1; and four density ranges, 0 to 1, 1 to 2, 2 to 3 and 3 to 4, are covered by this scale by the use of four interlocking pushbuttons. The extra 0.1 density range at the upper end of the scale provides overlap between successive ranges. Four potentiometer knobs on the left side of the meter case provide means for pre-setting the meter zero point for the three color and the two black-and-white filters. Contacts operated by the filter wheel automatically select the appropriate meter zero point for each filter in the optical path. On the right side of the

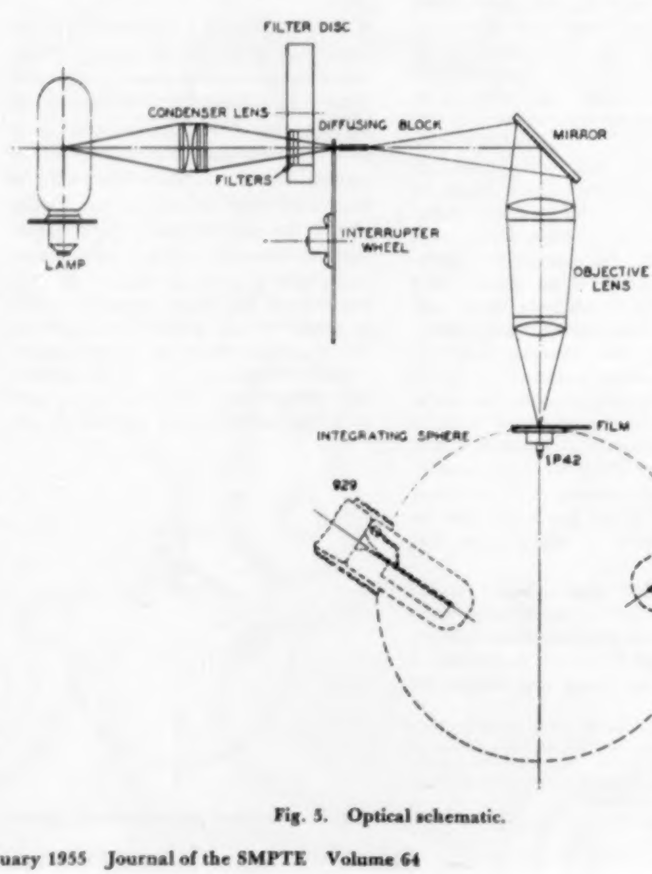


Fig. 5. Optical schematic.

(This paper was received on October 29, 1954.) **Fig. 2. Sketch of mirrors within sphere.** **Fig. 3. Illuminated surround.**

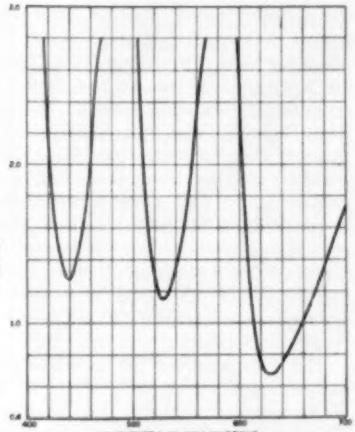


Fig. 6. Spectral characteristics of Eastman Kodak Status A Filters.

meter case is the knob controlling the calibrating potentiometer. The additional switches for operation of the instrument are located on the main panel.

Optical System

The optical system is shown schematically in Fig. 5. The light source is a standard tungsten lamp with a prefocus base. The filament of the lamp is operated at a relatively low temperature to insure long life and the current is supplied by a saturation type of voltage regulator which maintains constant voltage over a wide range of line voltage.

The condenser-lens assembly consists of a pair of plano-convex lenses and a Pittsburgh HA-2043 heat-absorbing filter. The image of the lamp filament is brought to a focus on a cylindrical block of glass, the length of which is chosen to eliminate the coil pattern of the filament at its exit. The cone of light, falling on this block, is interrupted by a synchronously driven interrupter wheel which gives a frequency of 375 or 450 cycles/sec on a power supply of 50 or 60 cycles respectively. The light from the glass block is reflected downward by an aluminum-coated first-surface mirror to the objective lens, which brings the exit face of the glass block to a focus at the film plane.

A color filter disk, which can be rotated to intercept the light beam with any one of five color filters, is located between the condenser lens and interrupter wheel. The filter disk is normally equipped with three Eastman Kodak "Status A" narrow bandpass color filters for measuring the integral color densities of Eastman color positives, and two filters for measuring visual and printing densities of black-and-white films. The filter disks are readily interchangeable and a second one is used to carry three "Status K" color filters to meet the different requirements for measurement of the color densities of Eastman color negatives. Different sets of color filters can be substituted for other color-film processes.

The Eastman Kodak Status A and Status K filters are made up of combinations of glass and gelatin filters. Their spectral characteristics are shown in Figs. 6 and 7 respectively. The filter for measuring the visual density of black-and-white film has been selected so that the resultant spectral response closely simulates that of the eye.

The printing-density filter provides a density reading of a black-and-white negative which is essentially the same as is seen by the positive film.

A densitometer, with the photocell located directly beneath the film sample, does not strictly conform with the American Standard for diffuse density. To employ this method for measuring the density of soundtracks would be a retrogressive step from the earlier types of the RA-1100 Densitometer which met the standard for black-and-white film. The RA-1100-F Densitometer was accordingly designed to provide integral diffuse density measurements of black-and-white silver sulfide and silver-with-dye soundtracks. The optical system for the type-F densitometer differs in five respects from that for the E-type instrument. Referring to Fig. 5, the glass block is rectangular instead of circular in cross section to conform with the rectangular scanning apertures. The illuminated surround has been eliminated since it is not particularly useful for soundtrack measurements. A metal slide just below the film plane contains a wide and a narrow light aperture, either of which can be centered easily on the scanning-beam axis. The wide aperture clears the scanning beam, the dimensions of which are 0.060 × 0.170 in. The narrow aperture limits the width of the light beam to 0.015 in.

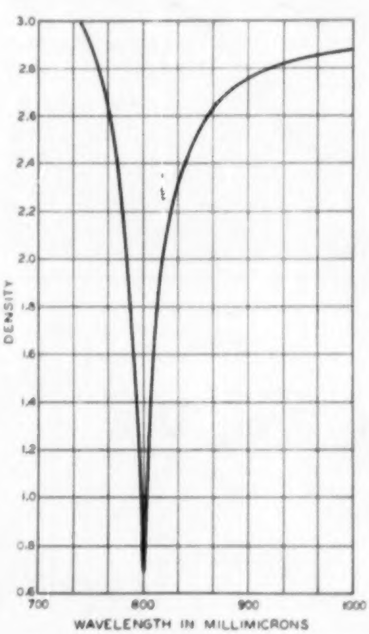


Fig. 8. Spectral characteristic of infrared filter.

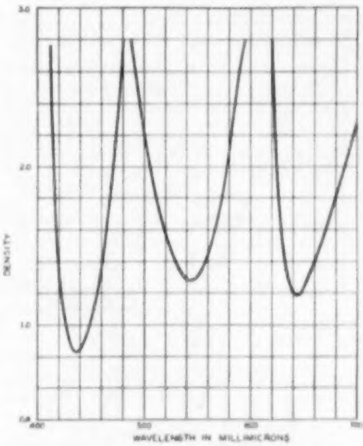


Fig. 7. Spectral characteristics of Eastman Kodak Status K Filters.

The 1P42 photocell has been removed and the usual integrating sphere has been restored to the instrument as indicated by the broken lines in Fig. 5. A 929 blue-sensitive photocell and a 925 red-sensitive photocell are located within the sphere in such a manner that any light reaching the cells has been reflected more than once about the internal surface of the sphere which is coated with magnesium oxide to insure maximum diffusion of the light.

The filter disk contains two color filters to provide measurements of visual diffuse and printing densities of black-and-white film. The 929-type photocell functions with these filters. The filter disk contains a third color filter, consisting of the combination of an interference and a glass filter to provide a narrow bandpass in the spectral region at 800 mμ. Its spectral characteristic is shown in Fig. 8. This follows the recommendations for the densitometry of silver sulfide soundtracks as set forth by Lovick.[7] This filter, in conjunction with the 925-type photocell, provides a thoroughly reproducible density reading of silver sulfide soundtrack measured at the peak wavelength of the spectral sensitivity of the average theater reproducer.

Since the heat-absorbing filter would interfere with the measurements at 800 mμ, it has been removed from the condenser lens assembly and one has been included in the visual-diffuse and printing-density filter assemblies.

Amplifiers

Two types of amplifiers are supplied in the type-E and type-F densitometers to meet the specific requirements for each instrument. In the type-E unit, a preamplifier and a main amplifier are used, as shown on the simplified schematic cir-

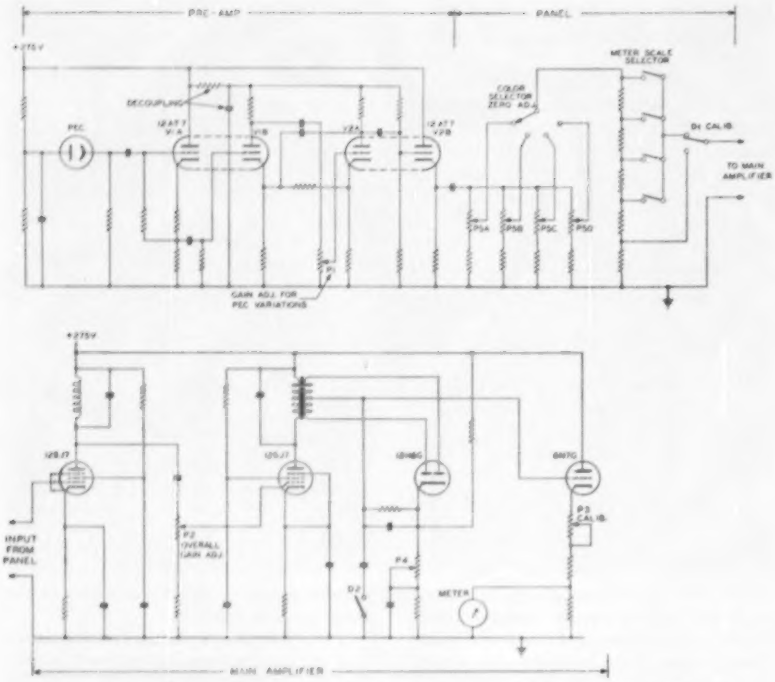


Fig. 9. Simplified schematic circuit of amplifiers used in Type-E Densitometer.

cuit in Fig. 9. The photocell output connects to a cathode-follower input stage (V1A) which provides a high input impedance and permits the use of a high-value of load resistance for the photocell. In this way a relatively high output voltage is obtained from the photocell.

The first stage is followed by two gain stages (V1B and V2A). The potentiometer P-1 in the grid circuit of V2A provides adjustable gain to compensate for variations in sensitivity of photocells or for the aging of the lamp. P-1 is adjusted to a level that will insure against overloading the preamplifier when measurements are being made of low-density black-and-white film. Positive feedback between the cathode of V2A and the cathode of V1B, and negative feedback between the plate of V2A and cathode of V1B are incorporated, the values of the components having been selected to provide a bandpass filter peaked in the region of 375 to 450 cycles/sec to obtain the necessary signal-to-noise ratio for low light levels.

The two gain stages feed a cathode-follower stage (V2B) which provides a low-impedance circuit in which the controls, for presetting the gain for the various color filters and for the four meter ranges, are located. The switch D-1 is the pushbutton switch, which when depressed, introduces 20 db attenuation to calibrate the upper end of the meter scale. The gain of the preamplifier is approximately 36 db and it is linear up to an output of 10 v.

The preamplifier drives the main amplifier which has two high-gain pentode stages of amplification, a twin-diode rectifier and an output triode. The plate circuits of the first two tubes are tuned to provide a bandpass characteristic centered at either 450 or 375 cycles/sec, depending on the line frequency operating the chopper motor. Potentiometer P-2 adjusts the overall gain and P-4 sets the operating point of the output tube. These are not operating controls and they are accordingly located within the instrument. Potentiometer P-3, together with D-1 and the gain control associated with the filter position being used (P-5), adjust the upper and lower points of the meter scale so that the full scale from zero to 1.0 covers a range of exactly 20 db or a density range of 1.0. The switch D-2 introduces additional meter damping automatically when the 2–3 and 3–4 density scale is used.

The main amplifier has an adjustable gain of nearly 100 db, of which about 86 db is normally required. The bandpass characteristic of the preamplifier plus that of the main amplifier are sufficiently selective to provide a signal-to-noise ratio of better than 10 db for the lowest signal input, namely that obtained with the Status K red filter and a film density of 4.0.

The amplifier for the type-F densitometer is shown in simplified schematic form in Fig. 10. The output from two parallel photocells (type 925 for infrared sensitivity and 929 for visual and print measurements) is connected to the grid of a low noise type 1620 pentode vacuum tube. In the cathode of this pentode are located three separate preset gain controls for the visual, print and infrared filter positions. Following the 1620 input stage is the range switch, of four positions, 20 db per step. This is followed by the pushbutton switch D-1 which provides 20-db attenuation compared to the 0–1 density position for calibrating the meter scale. After the range switch, are two gain stages with gain adjustable by the potentiometer P-2. As in the type-E densitometer described above, P-4 sets the operating point of the output tube V5. Output from the rectifier tube V4 applies negative bias to the 6N7-G metering tube, V5, resulting in decreased current through the indicating meter in the cathode of V5.

As in the type-E densitometer the 0 and 1.0 positions of the meter are adjusted by the use of P-5 and P-3 (which adjust respectively amplifier gain and static current through the 6N7 metering tube) in conjunction with switch D-1 which produces two signals of 20 db difference in level.

A bandpass characteristic is obtained in the type-F densitometer by the tuned circuit in the cathode of V2. This does not have as sharp a cutoff as in the type-E densitometer since the signal-to-noise requirements are not as severe.

Operation

The operation of the densitometers has been made as simple and rapid as possible. The power switch also controls the external power supply and voltage regulator. To use the E-type instrument, the

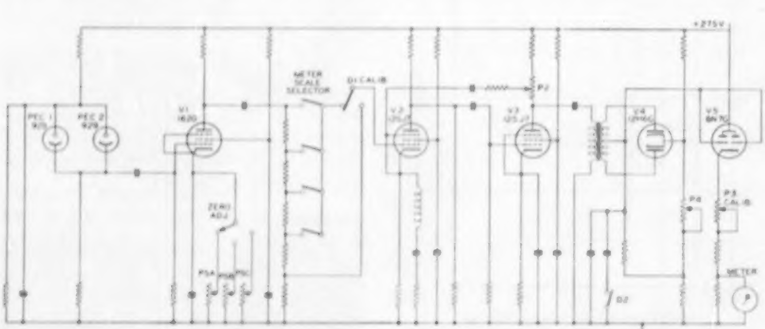


Fig. 10. Simplified schematic circuit of amplifiers used in Type-F Densitometer.

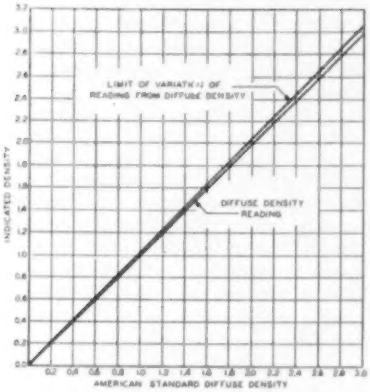


Fig. 11. Comparison of Type-E Densitometer readings with standard diffuse-density readings.

end points of the meter scale are first adjusted for each of the filters in the filter wheel. The adjustment for each filter consists of first setting the meter pointer to zero by means of the appropriate knob at the left of the meter panel. The pointer is then set to 1.0 using the righthand knob with the calibrate pushbutton depressed. The two filters for black-and-white film operate at the same zero setting. Thereafter it is only necessary to select the desired filter by rotating the filter wheel to obtain a density reading since the zero point for each filter is automatically selected by the position of the filter wheel.

To make a measurement, the film is placed in the gate with the emulsion side down. The illuminated surround facilitates locating the exact film area to be measured. When the density reading exceeds 1.0, the pushbutton marked 1–2 is depressed and 1.0 is added to the meter reading. If the density exceeds 2.0, the pushbutton marked 2–3 is depressed and 2.0 is added to the meter reading, and likewise to the next scale as the density exceeds 3.0.

Performance

The RA-1100-E Densitometer provides integral density readings of color and black-and-white film which closely approach the diffuse-density values as established in American Standard Z38.-2.5-1946. The maximum departure of the density readings from the standard diffuse values for black-and-white film are shown in Fig. 11. This shows that the instrument gives substantially diffuse density measurements of black-and-white films. The color filters used in the instrument have sufficiently narrow bandpass characteristics to provide reliable control of the negative-positive color processes in the film laboratories. A comparison of readings with those obtained with the Eastman Kodak Type 31A Densitometer from the same sensitometer strips using one of the green filters which is common to both instruments is shown in Fig. 12. Close agreement is obtained throughout most of the density range. Similar agreement is found between the two instruments for the red and blue filters. With the high signal-to-noise ratio obtained in the transmission system extremely stable operation is found even at density values as high as 4.0 with the most dense red filter in the optical path.

Conclusion

Notwithstanding the evolutionary changes that have been introduced into the successive models of the RA-1100 Densitometer, the desirable and convenient operating features, the basic fundamental principles, and even the general appearance have been maintained throughout. Every effort has been made to insure its universal acceptance as a standard for determining the photographic density of color as well as neutral-density film, for the control of film processing in the motion-picture industry.

Acknowledgments

The authors wish to express their appreciation to the Color Technology Division of the Eastman Kodak Co., Rochester, N.Y., for their suggestions of the arrangement of the photocell, its closely associated preamplifier and the zero presetting controls with microswitches operated by the filter disc, which served as a basis for the design described in this paper.

The authors also wish to express their sincere appreciation to Robert G. Hufford of the West Coast Division of the Motion Picture Film Dept., Eastman Kodak Co., for his considerable cooperation in bringing the described developments to a successful conclusion.

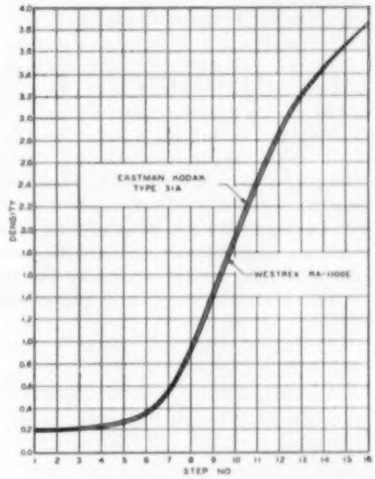


Fig. 12. Comparison of readings made on RA-1100-E and Eastman Kodak 31A Densitometers, using green filter.

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A Short History of Television Recording

By ALBERT ABRAMSON

This paper describes the development of the three basic television recording processes since 1927. It also describes the film-recording processes used in both the United States and Great Britain. The introduction of television recordings made on magnetic material in both monochrome and color is noted. The paper concludes with a short résume on the new art of electronic motion pictures produced with television cameras and recording facilities.

Television recording is an important part of the television industry today. Film recordings are made for a variety of useful purposes, some of which are: to compensate for time differentials, to delay presentation of a program to a more convenient time, and to provide network service to stations not connected by radio-relay or coaxial cable. In addition, programs may be recorded in advance to allow personnel to be elsewhere when the program is telecast, or even to provide a reserve program in case of emergency. As a result, the amount of film used to record programs by the major networks in the United States far surpasses that used by conventional film making means.

This recording of the television signal has been complicated lately with the adoption of a compatible color-television system. Since more and more network programs will be presented in color, a satisfactory commercial system of color recording must be developed that will have the same flexibility and speed as the monochrome recording. One of the answers to recording in color seems to have been solved with the introduction of magnetic television recording. This has been presented in both black-and-white and in full color, although only in a developmental stage. Magnetic television recording has many advantages such as: immediate playback of the picture, no development or chemical processing needed, and the saving if the magnetic material is used over and over.

Finally the possibilities of actually making high-quality motion pictures by means of television recording and electronic (television) cameras opens up a whole new field of endeavor. The advantages of this method have long been recognized but it has been only lately that equipment capable of the definition required has become available. It is to be expected that this process will eventually replace the more conventional film making methods.

Presented on October 19, 1954, at the Society's Convention at Los Angeles, by Albert Abramson, CBS Television, 1313 N. Vine St., Hollywood, Calif.
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Historical Development

Phonovision by Baird. Television recording is almost as old as television itself. To find the first efforts at recording the television image we must go back to the work of John L. Baird in England in 1927. Baird was a restless experimenter who covered the whole field of television. He tried long distance television, nighttime television, stereoscopic television and color television.[1] It is little wonder that he even tried recording television. This he did on a machine called the Phonoscope.[2] Baird was experimenting with a process of "Phonovision" which was the recording of the television signal on phonograph records. At this time, Baird was transmitting a 30-line picture at a rate of 12½ frames/sec. Thus the signal was actually of a very low frequency, so low, that it was easily carried on a regular telephone line or impressed on a wax record. The amplified signal was carried to an ordinary stylus head where the "picture" was converted into vibrations on the surface of the record. If desired, a synchronized record could be made of both the picture and the sound with either a double track being made, on one record, or else recording the sound on an accompanying record. To reproduce this record all that was necessary was a turntable synchronized with a scanning disc. The vibrations were converted back into electrical impulses which were fed to a neon light which illuminated the apertures in the scanning disc. Undoubtedly they were of poor quality for they were subject to the limitations of the crude mechanical system that produced them and there were other losses in the recording and reproduction processes. Baird soon tired of this facet of television and went on to more promising aspects of the field. However, we must credit him with making the first television recordings.

Rtcheouloff's Magnetic Recorder. While Baird was experimenting with his stylus recordings of the television signal another man filed a patent in England on January 4, 1927, for a process of recording the television signal on magnetic material. This was B. Rtcheouloff who indicated apparatus "...adapted for the production of a magnetic record of the Poulsen telegraphone type." Poulsen was the Danish physicist who invented magnetic recording in 1898. Rtcheouloff's patent indicated that the accompanying sound was to be recorded on the opposite side of the magnetic material. At the receiving end the record was to feed several television receivers and the telegraphone receivers.[3] There is no indication that this apparatus was ever built.

Hartley and Ives. On September 14, 1927, Hartley and Ives of Electrical Research Products proposed a new method of "interposed" film at both the transmitting and receiving ends. The reasons given were as follows: "Television of background details is improved and increased illumination is obtained by taking a kinematographic film of the scene to be transmitted." Thus they proposed a method of television in which the scene to be transmitted would first be filmed by conventional methods and then the resultant film would be scanned for transmission. They also stated that "...preferably a photographic process is also interposed at the television receiving station."[4] This, of course, is the basis of the "intermediate film" process which later came into being as one means of producing large screen television.

Thus the period of 1926—27 saw the birth of the three basic television recording processes; however, of the three, only one, the film recording process or "intermediate film" method, was to be of any consequence for the next twenty-five years.

During the early 1930's there were many attempts to project a large-screen television image. Most of these used large scanning disks with powerful arc lights modulated by a Kerr cell. But many experimenters tried to take advantage of the regular motion-picture film projector and its greater light-throwing capacity.

Lee De Forest's Large-Screen Projector. De Forest and his associates filed a patent on April 24, 1931, for a method of recording pictures, film or events, "at the receiver by the etching action of an electrical discharge upon a suitable coating applied to a moving picture film or strip."[5] Their apparatus consisted of a revolving wheel with a series of needle-points. These needle-points were connected to the receiving apparatus which impressed the video signal upon them. These points passed over a strip of

moving 35mm film which was coated with pure metallic silver. As the impulses varied, so did the etching action of the needle-points as they passed over the film. Thus the dark and light portions of the picture were to be reproduced as modulated lines on the film. This etched film was to be projected on a standard motion-picture machine.[6] However, due to many difficulties, this method was soon abandoned as impracticable.

The Intermediate-Film Process

The Intermediate-Film Transmitter. Another attempt at large-screen television was made by Fernseh A.G. in Germany. In 1932 they introduced their "intermediate film" transmitter at the Berlin Radio Exhibition. This was a television apparatus that first photographed the image to be transmitted by means of an ordinary motion-picture camera.[7] The scene was photographed on film prepared with a rapid and sensitive surface. This film was then passed through tanks where it was developed, fixed and washed, and while still wet (or in some cases after it had been partially dried) fed through a film gate in the last tank. Here it was fed to a scanning disk where it was dissected for transmission. After transmission, the film was either resensitized for immediate re-use or else saved for future transmission.

The Intermediate-Film Receiver. At the 1933 Berlin Radio Exhibition Fernseh again demonstrated this intermediate-film transmitter. Also in this year they demonstrated for the first time their "intermediate film" receiver for large-screen television.[8] Here the received signal was "recorded" on motion-picture film and then rapidly processed and projected by a standard motion-picture machine onto a full-size screen.

At the receiving end, the television signals were made to modulate a powerful beam of light by means of a Kerr cell. Between the cell and the film was a scanning disk with 90 hexagonal holes. This was rotated at a speed of 3000 rpm. Thus with 25 frames/sec a 180-line picture was obtained. The resultant light was focused on the film by a special optical system.

An image of the aperture in the disk was focused onto the sensitized film that was passing down a recording window. In this manner a series of adjacent lines of varying amounts of light and shade along each line, were imprinted on the film, so building up a picture. The film was rapidly developed and fixed. It was then fed into a theater projector of the usual intermittent type. The picture was 10 ft by 13 ft in size.

Thus the first television film recordings were made in 1933. This system was again demonstrated in 1934 using the same apparatus. The film was either saved or resensitized as in the intermediate-film transmitting process. The results were often marred by blotches on the film. There was a delay of some 20 sec between the time the image was received and the time it was projected on the screen.

In 1935 the intermediate-film receiving system dispensed with the mechanical scanning disk and the Kerr cell in favor of a cathode-ray picture tube. A patent was taken out by Rolf Möller of Fernseh A.G. in Germany on December 12, 1934, for recording television images on film from a cathode-ray tube using continuously moving film. This apparatus was shown at the 1935 Berlin Radio Exhibition.[9] Thus the first cathode-ray film recordings were made during the period of late 1934 and shown publicly in 1935. However, this new intermediate-film receiving system was not successful and was not shown at the annual radio exhibition in 1936.

The Visiogram. In England there also were interesting attempts made to record television images. A novel machine called the "Visiogram" was developed by Edison Bell Ltd. in 1934. Motion-picture film was used, with the television signals being recorded thereon by the variable-density method familiar in sound techniques. The video signal was not converted into the usual light values of the scene itself but into a modulated "sound" track of the image. By means of a simple attachment the film signals were to be translated back into a visual image in an ordinary television receiver. In a demonstration given to the press the results were extremely poor.[10] Both intermediate-film transmitters and receivers were studied in the laboratories of Fernseh A.G. in 1937; the intermediate-film receiver method disappeared in Europe after 1937. It was revived after World War II when one of the major American motion-picture companies turned to it as one solution to the large-screen television problem. It was to be many years before it would be possible to project an image as large or as bright with a cathode-ray projector as with the intermediate-film receiving process.

Early Film Recording in the United States

In 1938 the first attempts were made in the United States to record on film the screen of a cathode-ray picture tube. These early efforts used standard silent, 16mm, spring-wound cameras operating at 16 frames/sec. With the low light intensity of the monitor screen, it was necessary to use the fastest film emulsion then available.

Since the cameras were nonsynchronous with the 30-frame rate of the television screen, the film recordings were marred by the appearance of banding or horizontal lines (shutter bar) of over and under exposure caused by the uneven matching of the odd and even fields recorded on each frame of film.

The film was then recorded at 15 frames/sec which succeeded in eliminating banding but was successful in recording only every other frame of the television 30-frame picture.

It became obvious that if commercial use was to be made of television film recordings in the United States, the 30-frame television picture would have to be recorded on film at 24 frames/sec to conform with the speed of standard 16mm sound film, thereby permitting projection of the film either in a conventional sound projector for direct viewing, or by a standard projector for rebroadcasting by television. Development of a suitable commercial television recording camera was to continue for the next ten years before a practical system was perfected.

Recording of Airborne Television Transmissions. Although commercial television started in the United States in 1939 there was no further development in television film recording until the middle of World War II. Experiments with airborne television equipment such as "Project Ring" and the "Block" system were carried out. With the development of "Block" and "Ring" equipment, it became necessary to make permanent records of the transmissions of this apparatus. Motion-picture film cameras were used to record the television images sent by these developments from aircraft and guided missiles. Film cameras were installed on television receivers on the ground and in other aircraft. One of these early motion-picture cameras was a standard Air Force camera with a speed control to adjust the shutter to about 8 frames/sec. Speeds as low as 4 frames/sec were available. The recorded pictures were very poor due to the different standards of the transmissions, the low light intensities of the recording monitors, and to the many steps involved in the photographic processes. Shutter banding was noticeable in the film but did not destroy its value as a record. Further work was done with a Cine Special camera at 15 frames/sec with a 170° open shutter.[11]

During the immediate postwar period there was created a new interest in the recording of television images. The U.S. Navy started a series of experiments with its airborne television equipment. The first postwar black-and-white television film recordings were made on March 21, 1946, at the Naval Air Station at Anacostia, D.C. These were secured during a public demonstration of the Navy "Block" and "Ring" airborne television equipment.

Need for Commercial Film Recording. The rapid growth of the television industry also necessitated the use of commercial film recordings. Television stations in the United States were opening faster than the telephone company could lay coaxial cable or erect radio-relay stations. With many new stations commencing operation it became necessary to serve them with program material from the two great centers of production, New York and Hollywood. Therefore the television film recording or transcription filled this need for program material.

Paramount's Large Screen Method. The film recording became one of the prime methods for large-screen television also. Paramount Pictures chose the "intermediate-film" method of recording for their large-screen television system. Paramount selected this system over the other immediate cathode-ray methods for a variety of reasons. Some of these were: the opportunity for cutting and editing the program before presentation; flexibility of programming around the regular film showing; and the use of regular projection equipment at the usual high light values.

With these advantages in mind, Paramount developed an intermediate-film system which used 35mm film exclusively. It used a special 35mm single-system (both sound and picture recorded on the same film), recording camera built by the Akeley Camera Co. This camera was unique at the time in that it used an electronic shutter. It could be loaded with 12,000 ft of film which permitted recording of over two hours. A Cooke $f/1.3$ coated lens was used at normal aperture, $f/2.3$. Du Pont Type 228, fine-grain, master positive film or Eastman 5302 film was used for recording either positive or negative pictures.

The film was processed by high-speed developing machines, in approximately 66 sec and was fed by a chute directly to a standard motion-picture projector.[12]

The Eastman Television Recorder. In January 1948 Eastman Kodak announced their new 16mm motion-picture camera for rerecording television programs on film. It had been developed in cooperation with NBC and the Allen B. Du Mont studios. It featured a 1200-ft magazine for continuous recording of a half-hour program, separate synchronous-motor drives for the shutter and film-transport mechanism an $f/1.6$ 2-in. lens, and a 72° closed shutter. The pulldown time was 57 degrees. Other features included a "bloop" light to provide registration with a sound-film recorder, a film loop-loss indicator, and appropriate footage indicators.[13]

First Color-Television Recordings. The first color film recording was made on August 18, 1949, in Washington, D.C. The film camera used was the Navy's Berndt-Maurer with a 25mm $f/1.4$ Cine Ektar lens. Daylight Type Kodachrome was used. Exposures were made at 15 frames/sec synchronous, and at approximately 8 and 4 frames using the hand crank. The results were quite promising, in that the exposures at 8 and 4 frames were both adequate.

Other cameras were used and it was claimed that the "...first completely successful color recordings were made from a CBS Color Television receiver at the speed of 25 frames per second." On February 6, 7, and 8, 1950, sound was recorded with the picture to make the first sound and picture color film recordings.

The first color recording of the RCA "dot sequential" color television system was made at the RCA Silver Spring Laboratory on March 10, 1950. The initial recording was made at 15 frames/sec with a 180° open shutter, the exposure time being one-thirtieth of a second. It was claimed that all exposures were good and, "...strangely enough, it was the consensus of opinion that the film record was superior in quality to the image on the color television receiver as viewed with the naked eye. This phenomenon may be partially explained by the fact that the recording camera lens was located on the axis of, and normal to, the color television image, whereas the observers were forced to view the image from an 'off center' position."

The last of the three experimental systems, the "line sequential" system of Color Television, Inc., San Francisco, was recorded from an RCA Receiver on March 16, 1950, for the first time. This was made at 15 frames/sec.[14]

Early Film Recording in Great Britain

Similar progress in television film recording took place in England immediately after World War II. However, the need for recordings was different since there was only one television station in operation right after the war. The English realized that many topical events occurred when the majority of viewers were unable to see the direct transmission. Also they considered it a waste of time when recording topical or news events to have both newsreel cameramen and television cameras cover the same event. This is especially true when the televised event can be recorded and readied for broadcasting in such a short time compared with the regular filmed version. In addition the British had developed the habit of repeating dramatic programs a few days after the original performance. The use of television film recording allowed them to repeat a performance without added expense of cast and crew.

188½-Line Recorder. The 1947 efforts of the British to record television programs on film were done along the same pattern as the Americans. They tried to use intermittent recording cameras with quick pulldown times. Here they faced a tremendous problem. They had to record a 25-frame television picture at 24 frames/sec and the amount of pulldown time was about 12°, so they compromised by recording only 50% of the television picture using the other 50% for pulldown time. These recordings were made on 35mm film but recorded only 188½ lines of the British 405-line picture.[15]

16⅔-Frame Recorder. Later in 1947 they used another method of intermittent recording. A special shutter was designed which recorded for 240° and was closed for 120°. This produced a film recording that was nonstandard, being recorded at 16⅔ frames/sec.[16] This recorder was also abandoned for a new one that used no intermittent mechanism at all.

The Mechau 35mm Recorder. Early in 1948 a 35mm continuous motion picture projector, the Mechau made by A.E.G. in Germany, was converted to a camera for continuous recording. It had a rotating mirror drum which for all practical purposes produced a stationary film frame. It used a form of optical compensation where as the drum rotated in sync with the film, the varying tilt of the mirrors made the reflected images of the television picture follow the film on its downward course. Thus the image was stationary in relation to the film. In this way a succession of images was formed on the film as it passed through the gate, the brilliance of each image rising from zero at the top of the gate, then increasing to a constant intensity over the central part of the gate and finally falling to zero at the bottom of the gate. This method eliminated any frame rate difference. This machine also eliminated the high rate of pulldown and the problem of the "picture splice" in the center of the frame common to the United States. There were no lines of the television picture lost in the recording process. It was claimed that this method could be used in the United States by blacking out a portion of the mirrors to avoid more than two fields being recorded on a single frame.[17]

Experiments with this equipment showed that the mirror drum was fully capable of providing correct optical compensation; however, the film transport mechanism did not attain the same high standard. Therefore the equipment was redesigned completely and three machines of this new type were to be installed in 1953 at the Lime Grove television studios.[18]

Application of "Spot Wobble." In addition, there was added an ingenious system of spot position modulation to eliminate the line structure that forms the television image. This was the application of a 10- to 15-mc modula-

tion to the scanning beam. This caused the electron beam to oscillate vertically as it swept across a line and thus spread out. This increased the effective height of the scanning spot without increasing its width. It was claimed that a gain in light output in the order of two to one was made possible by the application of the "spot wobble."[19]

Double Gate 16mm Recorder. While this continuous recorder was more than satisfactory with 35mm film, more economical methods of recording became desirable by 1950 and development was concentrated on 16mm film. Due mainly to the fact that no continuous motion mechanism had been developed for 16mm film it was decided to develop a new recorder using an intermittent movement. This new 16mm film recorder had a double gate, that is, one gate above another, with an optical system capable of producing two images, identical in size, shape, and brightness at the normal 16mm frame spacing. A special pulldown mechanism was designed to work at 90°.

A full frame with two fields was recorded in the bottom aperture and then the second field of the first frame and the first field of the second frame recorded in the top aperture. The second field was lost and the film advanced two frames in this period. This cycle was then repeated. This gave an average film speed of 25 frames/sec. This recording camera gave good general definition with excellent interlacing. Movement was satisfactory although some jerkiness could be detected, especially on pan shots.[20]

Continuous Recording. In addition to the continuous mirror drum system and intermittent methods using either one or two gates there is a third method for recording television images on film. This was actually the oldest system of all as it was the basis of Fernseh's "intermediate-film receiver of the early 1930's. With the use of short decay and buildup phosphors, it was possible to make continuous recordings of television images from a cathode-ray picture tube, for example, merely by using the film motion as the vertical sweep and allowing it to spread a complete record of each frame of the television picture along the length of the film. There were no complications due to the difference in frame frequency and shutter frequency since there was no shutter used on the camera. This method is used in the present day "Ultrafax" facsimile recording apparatus.[21]

Magnetic Television Recording

Another advance in television recording was made on November 11, 1951, when the Electronic Division of Bing Crosby Enterprises gave its first demonstration of a video tape recorder in black-and-white.[22] The advantages of recording video signals on magnetic tape are many.

1. There is no lens system necessary, as there is in the film-recording camera. Thus all optical losses are eliminated.
2. The signals are recorded as electrical waveforms and not as visible images from the face of a cathode-ray monitor tube with its possible distortions and limitations.
3. There are no problems of pulldown time or frame-rate conversion.
4. There are no developing processes, and so losses due to chemical action and image transfer are avoided.
5. The video tape recording can be played back immediately.
6. Magnetic tape is cheaper than processed motion-picture film and can be used over many times if necessary.
7. It will eventually allow full color, stereoscopic pictures with stereophonic sound to be recorded on one strip of magnetic tape.

However, the recording of a video signal on magnetic tape presents many unique problems. Since the signal cannot be spread horizontally as it can in film recording, it must be spread along the length of the tape. It is possible to record the signal by use of special recording heads capable of responding to a 3- or 4-mc signal. Or the signal may be divided among a series of heads for recording. In either case the tape must be run many times faster than sound recording speed. The problem is also complicated by the fact that the tape must run at an absolute constant rate of speed. In addition, it must be remembered that the television signal consists of other necessary information such as synchronizing pulses. Finally, the tape must be played back on the same standard of definition (number of lines and frames/sec, etc.) as it was recorded.

A multiple-track method was chosen by the Electronics Division of Bing Crosby Enterprises for their first video tape recorder.[23] This apparatus used twelve recording heads. Ten were used to record the video signal, the eleventh was for a synchronizing track, and the twelfth was for recording audio. By combining an ingenious method of sampling each head in a stroboscopic manner with a unique switching device, an alternating signal was recorded on each track, with both positive and negative halves representing bits of picture information up to 1.69 mc for the whole group of ten heads. Early models of this apparatus used 1-in. brown oxide tape although later models use either one ½- or ⅜-in. tape. The tape ran at a speed of 100 ips. The recorder accommodated reels for 16 min of recording.

The October 2, 1952, demonstration of this video tape recorder proved that this process merited attention. The picture had the following good features:

1. The gray scale was outstandingly good.
2. The picture was sharp and clear.

However, the following faults were apparent:

1. A diagonal pattern was always prominent.
2. Considerable flicker was noticeable.
3. Under certain conditions a series of ghosts was noticeable.[24]

Later developments by the Crosby Organization have resulted in highly improved definition of the picture and elimination of most of the previous deficiencies. The number of tracks required has been greatly reduced for black-and-white recording, thereby making the system more easily adaptable to color recording.

The RCA Video Tape Recorder. The Radio Corporation of America on December 1, 1953, demonstrated at the David Sarnoff Research Center a video tape recorder on both monochrome and color. It proved that the recording of images in color was as easily accomplished as in black-and-white. The recorder used paper thin plastic tape running at 30 fps. The reels were 17 in. in diameter and would record some four minutes of a program. RCA had achieved the recording of a 3-mc signal through the use of specially designed recording and reproducing heads which responded to frequencies much higher than the cutoff point for heads used in sound recording.[25]

The black-and-white programs were recorded on ¼-in. tape, using two tracks, one for the picture and synchronizing signal, and the other for the sound portion. The color program was recorded on ½-in. tape, using five tracks. Three tracks were for the colors, red, blue and green, one was for the synchronizing signals and the last was for the audio portion. The playback of the color recording showed only a slight loss in definition, mostly in excess light values. There was a slight smearing, streaking and halo effect, as well as a high-frequency noise level hiss. Occasionally there was some jitter due to nonuniform speed control. However, the demonstration was considered to be an overwhelming success.

It is expected that these problems will be overcome and that video tape recording will emerge from the laboratory capable of reproducing pictures indistinguishable from the original "live" pickup. It is expected that this process will supplement if not supplant the film or visual recording.

The Electronic Motion Picture

A whole new field of television film recording is being introduced by the development of a completely new electronic picture recording system by High Definition Films Ltd., in London,

which has a new concept of producing high-quality motion pictures, utilizing electronic (television) cameras and advanced film recording techniques.

High Definition Films Ltd. Norman Collins and T. C. Macnamara have carefully pointed out the limitations of ordinary film-making procedures while indicating the advantages of using the electronic camera.[26] Avoiding ordinary television broadcasting requirements, they are not bothered by such items as a restricted bandwidth, limited contrast range and tonal gradation, and the necessity for mixing in synchronizing signals. The whole apparatus is operated on closed-circuit under virtually laboratory conditions.

In the development of this equipment, it was decided to equal the standards of present 35mm motion-picture filming. This was accepted as some 30 to 40 lines/mm resolution. To equal this definition a 24-frame picture would have to have 992 lines with a bandwidth of 15.75 mc/sec. This may be increased to 1300 lines if necessary. However, it was felt that it would not be necessary to go much above a thousand lines to equal today's 35mm film standards.

The line scanning is sequential. It is known that interlacing is not needed for pure film recording purposes. Interlacing's main advantage of eliminating flicker while conserving available bandwidth does not overcome some of its more serious faults. These include "line-pairing," "line-crawl," and movement blur. Since in this system, the picture signals are kept separate from the synchronizing signal, the line frequency does not have to be related to the frame frequency. This simplifies the pulse generating apparatus and also enables the number of lines to be varied to suit the resolving power of the type of pickup tube selected.

When recording television images on film, any apparent flicker will be eliminated by the film projector due to its interruption of the light source two or three times during a frame. However, it was expected that monitoring would be difficult, but that the 24-frame flicker could be reduced by using cathode-ray screens having long delay times.

The recording unit is of the intermittent type. While it was felt that continuous motion was exceedingly attractive from many points of view the accuracy of registration which could be realized at the present state of development was insufficient for recording picture of the high definition required. In 1952 a standard film camera with a 70° pulldown was being used. The lens was also a standard motion-picture 75mm type operated at full aperture of *f*/2. Recording was on a slow, fine-grain sound recording stock.

Refinements of the High-Definition system were made and it was presented with the following features in 1954.[27]

1. The cameras in England were the Pye Radio type using the Pye Photicon image iconoscope pickup tube. Cameras for use in the United States and Canada were the General Precision Laboratory type using the 5826 image orthicon pickup tube.

2. The cameras used sequential scanning of either 625 or 834 lines per frame at 24 frames/sec.

3. The chain is essentially closed circuit with a bandwidth of 12 mc.

4. The picture and synchronizing signals are never mixed and a new method of signal control has been devised.

5. A special "staircase" signal is present on all picture monitors in the form of a step wedge. Its presence allows accurate adjustment of the signal amplitude and lift.

6. On the recording monitor two photocells are used for measuring brightness of the first and tenth suppression steps on the kinescope tube face. The monitor tube is a special HDF/Cintel tube with a 9-in. diameter flat screen, free from granularity, and aluminum backed. It presents a 3 × 4 in. picture.

7. The High Definition system employs a spot wobble oscillator to eliminate line structure.

8. There are two recording channels using HDF/Moy 35mm film cameras. These cameras have a specially designed 20° pulldown mechanism with a special film accelerator.

9. This system is designed to use any kind of sound recording method.

High Definition Films has acquired studios in London and was producing demonstration films by this process early in 1954.

Television recording has come a long way from Baird's crude grammophone recordings to today's high-definition film recordings. The television recording has an important place in the commercial television industry. It promises to play an even more important role in the motion-picture industry of tomorrow. The electronic motion picture using neither film cameras nor motion-picture film is an actuality. The television camera and the magnetic video recorder will allow the motion picture a perfection and flexibility that has never before been attained.

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Stereography and the Transmission of Images

By EDWARD LEVONIAN

In this paper a given theory of the perception of visual stimuli is used as a basis for investigating the principles of stereoscopic cinematography. Part I states the vision theory selected and expresses this theory mathematically in a manner applicable to the 3-D spectator. Part II uses this vision theory to develop formulas for filming the scene. Part III applies these formulas to the mechanics of filming. In Part IV accuracy considerations are investigated for the entire transmission chain from scene to screen.

In analyzing stereoscopic cinematography with respect to the transmission of the visual image, it should be understood from the outset that a precise analysis is impossible with our present limited state of knowledge. One difficulty lies in the fact that the image, in its transmission from a light stimulus in the physical world to a perception in the mind of the spectator in the theater, is transformed several times, and some of these transformations defy a coordination to numbers. For this reason resort has been made to two types of treatment: an analytical one for those stations where the transmission of the image can be defined mathematically, and an empirical treatment for the remaining stations.

The difficulty of analyzing the 3-D film is further compounded by the fact that perception is partly a function of the psychological condition of the spectator, a condition which varies not only among spectators but also in a single spectator at different times. Since it is impossible to account for each variation in perception, the manner of transmitting the 3-D film can concern itself only with the average spectator. In the general case, therefore, the perception of the scene in the theater can only be an approximation of the perception which would have resulted had the spectator viewed the original scene.

I. VISUAL TRANSMISSION

In order to transform the object in the scene to an image in the theater, a coordinate system at the camera must be related to a second one in the theater. Since the problem is basically that of transforming the Euclidean space manifold into a visual space manifold, the particular method of coordinating the two manifolds will depend on the manner in which depth is perceived. A choice of one of the principle theories of stereoscopic vision must be made since there exists no generally accepted theory. Charnwood lists the three principle theories as outlined by Tschermak:[1]

(1) Projection theories, which place the sensed image at the intersection of the two optic paths through the centers of the eyes.

(2) Oculo-motor theories, which relate the placement of the sensed image to the proprioception of the extraocular muscles.

(3) Local sign theories, which accord to visual elements, both at the retina and at higher centers, functional space values.

Selection of a Vision Theory

Of the three principle theories stated above, one must be selected to be used as a basis for the development of the formulas of transmission.

The first theory, the projection theory, bases its validity on the premise that the angle of the optic path to an object stimulus determines the localization of the object. Examples can be given which indicate the limitations of attempting to determine apparent location by means of geometric methods only. For instance, it is known that the composite 3-D image does not always appear at the intersection of the two optic paths through the point pairs on the screen. Furthermore, a slanted line in the absence of other clues can eventually appear horizontal, in spite of the fact that the angle of the optic path remains constant, and in fact, if a truly horizontal line is then introduced, it will appear slanted.[2]

The second theory, the oculo-motor theory, relies on the information obtained from movements of the extraocular muscles. These muscles are constantly in motion even when the spectator is fixating a point, a condition known as physiological nystagmus, and this movement is independent for each eye.[3] Nevertheless the point appears stationary in spite of the fact that the amount of this erratic eye movement is much greater than that necessary to localize separately two nearby points in space.[3] Furthermore one cannot dismiss this evidence of the lack of absolute information relayed to the mind by the proprioception of the extraocular muscles by assuming that only willful innervation of the muscles has an effect on depth perception. Langlands has found that a sense of depth occurs even though the duration of the stimulus is less than 0.01 sec. Since the reaction time of the extraocular muscles is in the order of 0.1 sec, proprioception of the muscles must certainly have been absent.

The foregoing arguments imply that neither the angle subtended by an object in front of the camera nor the position of the object with respect to the camera can be used as a basis for transposing the object to its approximate equivalence in the theater. That neither form nor localization uniquely determines perception is revealed by the work of Luneburg and Ames at the Dartmouth Eye Institute.[4] Their research concludes that differing space patterns viewed binocularly can be perceived as congruent to each other. Likewise, examples of differing interpretations by one or several observers of a single stimulus are so common that it seems unnecessary to labor the point. Yet to deny the existence of any sort of relationship between stimuli and perception is to ignore common experience.

The third vision theory, that of local signs, attempts to account for variations in perception by relating only certain aspects of visual stimuli to visual sensations. This paper is based on this theory in general and on the hypothesis of Luneburg in particular. This hypothesis states that the assignment of apparent size to an elemental line is a primitive sensation. The proof of this hypothesis is beyond the scope of this paper, and reliance is placed on the reader's acceptance of Luneburg's monograph.[4]

It should be understood that the hypothesis makes no claim of uniquely determining preception. Since the visual manifold contains objects of finite size, individual integration of elemental lines to yield finite objects results in an additional constant which varies among individuals. Thus Luneburg's hypothesis relates only one aspect of visual sensation to the physical world. To transform this sensation into a perception in the theater necessitates empirical considerations. Such considerations have already been treated by Hill.[5]

Luneburg's Hypothesis and the Spectator

Luneburg's hypothesis, namely that the comparison of small line elements yields an extra-psychological sensation, will now be employed in conjunction with an approximation which will simplify the mathematics involved. Luneburg states that visual sensations cannot be represented in general by a Euclidean coordination, for if, as he has intended to

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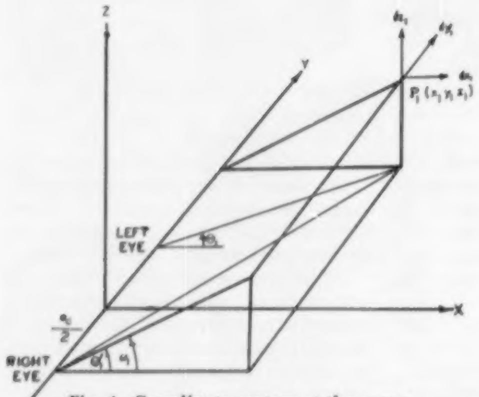

Fig. 1. Coordinate system at the scene.

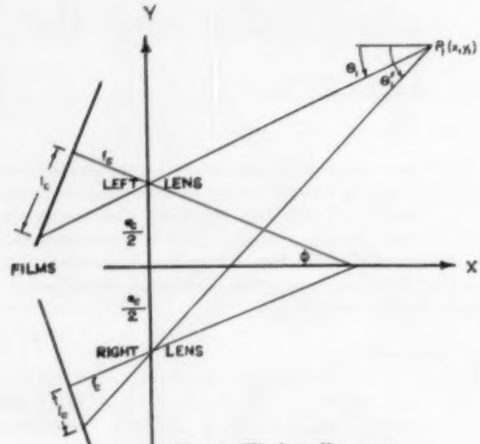

Fig. 2. Filming diagram.

prove, visual sensations comply with the geometry of constant curvature, no isometric mapping of the non-Euclidean geometry of visual sensations is possible in a Euclidean coordination. Nevertheless Luneburg shows that when the convergence angle of the eyes is small, as it is in viewing 3-D films, the visual world can be approximated by the Euclidean manifold. This approximation is used in the following development.

It is now desirable to express mathematically the conditions necessary to guarantee that an extra-psychological sensation of the image of an elemental line stimulus in the theater will be identical to the sensation which would have occurred if the spectator had viewed from the camera position the actual elemental line in the original scene. To achieve this it is necessary to define coordinate systems at the scene and in the theater.

In Fig. 1, the origin of a rectangular coordinate system is attached to a spectator who is viewing the scene from the camera position. The system is oriented such that the y-axis passes through the effective nodal points of the eyes, while the x-axis lies in the median plane. This orientation corresponds to the y-axis passing through the effective nodal points of a bicentric recording device (a pair of cameras is one example), and the z-axis being normal to the effective film plane. Thus the spectator at the scene is oriented with the camera. The eyes are symmetrically located about the origin, and the semi-interocular is denoted by $e/2$. The line elements (dx_1, dy_1, dz_1) are attached to the general point P_1 located at (x_1, y_1, z_1). The angle of elevation of a plane through P_1 and the y-axis with respect to the x-y plane is denoted by ω_1, while the angles in the x-y plane made by the x-axis and the optic paths from each eye (or lens) to P_1 are signified by θ and θ_1'. The subscripts 1 refer to the original scene, while the subscripts 2 refer to the scene in the theater.

The coordinate system in the theater is also attached to the spectator and oriented in such a way that the x-axis connects the Cyclopean eye with the center of the screen. Thus the coordinate system is aligned with the normal position of the spectator. The original point P_1 and the original differentials (dx_1, dy_1, dz_1) are represented in the theater by P_2 (x_2, y_2, z_2) and (dx_2, dy_2, dz_2). As before, the angles of elevation and latitude are denoted by ω_2, θ_2 and θ_2' respectively.

Luneburg's hypothesis states that if the original differentials, characterized by $(d\omega_1, d\theta_1, d\theta_1')$, and the theater differentials, characterized by $(d\omega_2, d\theta_2, d\theta_2')$, are related such that

$$\begin{aligned} d\omega_1 &= d\omega_2 \\ d\theta_1 &= d\theta_2 \\ d\theta_1' &= d\theta_2' \end{aligned} \tag{1.1}$$

then the spectator in the theater will enjoy a sensation of the line element equivalent to the sensation which would have occurred had the spectator viewed the original scene.

A simplification of the mathematics in the next Part can be achieved by restricting the discussion to points in the x-y plane. Later in Part IV the significance of points other than in the x-y plane will be investigated.

II. STEREOGRAPHIC TRANSMISSION

The conditions for visual equivalence of scene to theater have been outlined in Part I. It is the purpose of Part II to express these conditions in terms of the geometry of transmission of the visual image from scene to screen. This requires

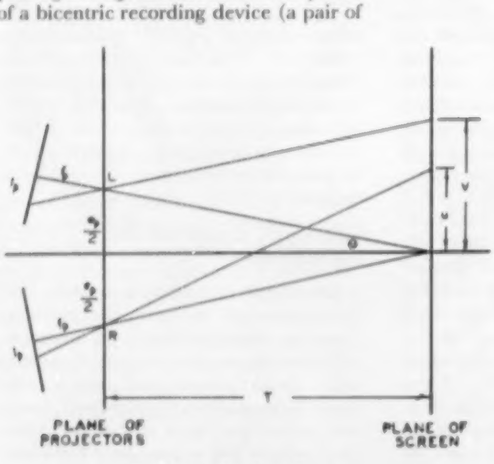

Fig. 3. Projecting diagram.

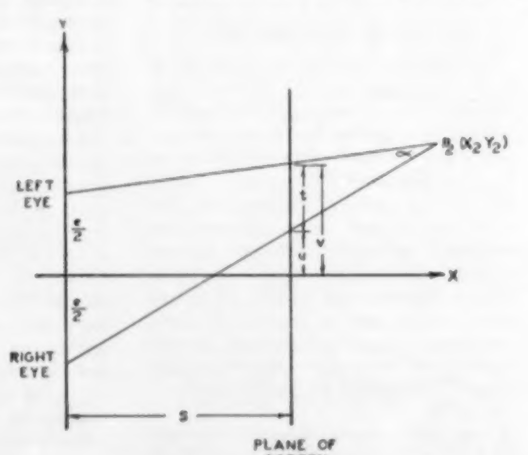

Fig. 4. Viewing diagram.

that (1.1) be expressed in terms of standard nomenclature used in motion-picture work.

Assumptions

The following assumptions will be made:

(1) A bicentric transmission system is assumed without implying the necessity of two separate cameras, projectors or films. However two conventional cameras and projectors will serve as a basis for discussion, though the results obtained are not restricted to this specialized form of a rectilinear bicentric system.

(2) The filming, projecting and viewing systems used are those of Figs. 2, 3, and 4 respectively.

(3) The left camera records the left aspect, which in turn is projected by the left projector.

(4) The cameras operate at essentially the same elevation angle, ω_1.

(5) The films are normal to the optic paths of the cameras and projectors.

(6) The optic paths of the projectors are essentially normal to the screen and converge at the center of the screen.

(7) The filming and projecting distances are large enough so that the lens-film distances can be represented by the focal lengths of the lenses.

(8) Some form of discrimination exists such that the left eye of the spectator sees only the left aspect. (The polarizing filter system is only one method of achieving this discrimination.)

(9) Viewing conditions apply only to those spectators seated down the centerline of the theater.

The following symbols will be used:

ϕ—half angle of convergence of cameras
θ—half angle of convergence of projectors
e—human interocular
e_c—camera interaxial
f_c—camera-lens focal length
M—magnification, the ratio of screen width to film width
E—enlargement, the linear alteration in image size between camera and projector films
s—screen distance, the distance from spectator to center of screen
x_1—distance from camera to object plane
x_2—distance from spectator to image plane
y_1—distance from median plane of cameras to object
y_2—distance from median plane of spectator to image
w_c—effective camera film width
h_c—effective camera film height

Subscripts $_c$ and $_p$ will refer to camera or projector.

Theoretical Filming Formulas

The following filming formulas for camera interaxial and convergence are obtained by combining the conditions for visual equivalence given in (1.1) with the geometry of transmission of the image.

The geometry of transmission is most readily seen by referring to Figs. 2, 3 and 4. It is seen that when the original point, P_1, is filmed and then later projected, it appears as a pair of points (called homologous points or a point pair) on the screen. The geometric or projected location of the composite point is then placed at P_2. It cannot be too strongly emphasized that the composite point will not necessarily appear at (x_2, y_2), for the apparent location is a function of psychophysiological factors not shown in Figs. 2, 3 and 4. This apparent location will be considered later.

The geometric distances in the theater are readily obtainable by applying simple geometric considerations to Figs. 2, 3 and 4. Thus[6]:

$$x_2 = \frac{es}{e + MEf_c\left(\frac{e_c}{x_1} - 2\tan\phi\right)} \qquad (2.1)$$

$$y_2 = \frac{MEf_c x_2 y_1}{s x_1} \qquad (2.2)$$

The limitations of the projection theory of vision have already been noted, and the above formulas, which give the location of the composite image according to the projection theory, reveal even further limitations of attempts to apply this theory to 3-D. Adherents of the projection theory of vision attempt to achieve a geometric equivalence of the image in the theater to the original scene. However, Eqs. (2.1) and (2.2) reveal that a bicentric transmitting system cannot reproduce geometrically even a single general point. It is seen that x_2 is a function of x_1 only, whereas y_2 is a function of both x_1 and y_1. Thus geometric equivalence of scene to theater can only be obtained for those points where y = 0, that is, for points limited to the center of the screen. For other points in the x-y plane x_2/x_1 must equal y_2/y_1, which can be met only if $s = MEf_c$. In practice this condition cannot be met because s, the spectator-screen distance, is determined by the spectator himself. Also, whereas f_c may change from scene to scene, s is constant.

Since camera interaxial and convergence must meet the conditions imposed by (1.1), (2.1) and (2.2), the filming formulas are obtained by combining these three expressions. By so doing, and by assuming that the rate of growth of the projected image to the original object must be the same for both eyes, the following theoretical filming formulas are obtained[6]:

$$e_c = \frac{es}{MEf_c} \qquad (2.3)$$

$$\tan\phi = \frac{e}{2MEf_c} \qquad (2.4)$$

where e_c is the interaxial and ϕ the angle of convergence of either camera.

If camera interaxial and convergence are those given by (2.3) and (2.4), and if the projectors converge at the center of the screen, the visual sensation of an elemental line in the x-y theater plane cannot be discriminated from its original stimulus counterpart if the spectator had viewed the original stimulus from the camera position. However, objects are perceived as integrated shapes, not infinitesimal line elements, so that it cannot be assumed that the application of (2.3) and (2.4) will guarantee an equivalence of shape from the scene to the theater. Furthermore, practical considerations require a modification of the theoretical filming formulas; these considerations will be investigated in Part III.

Apparent Location

Before proceeding to the mechanics of filming, it is best to introduce first a simplifying concept, that of apparent location. The apparent location, denoted by A, is a measure of where the composite image point will actually appear to the centerline spectator irrespective of his distance from the screen. The use of the concept of apparent location allows the director and cameraman to place any arbitrary point P_1 in the original scene at any desired location in the theater.

For this kind of control it is seen from (2.1) that the apparent location must be independent of s, the spectator's distance from the screen, for this is the only quantity in (2.1) that is unknown at the time of filming. A second characteristic is incorporated into A in order to give the apparent distance a truly perceptual quality. To do this it is simply necessary to relate the geometric distance of the image point as given by (2.1) to the apparent distance of the image point by the application of a psychophysiological factor, φ.

By definition then,

$$A = \frac{\varphi x_2}{s}$$

or

$$A = \frac{\varphi e}{e + MEf_c\left(\frac{e_c}{x_1} - 2\tan\phi\right)} \qquad (2.5)$$

In order to utilize the apparent location, A, it is necessary to determine values for the factor φ. To achieve this by analytical methods is impractical because of the large number of interdependent variables involved. A few of these variables are probably the spectator's distance from the screen, his variation of convergence from accommodation, the geometric distance to P_2, the nature of the subject matter being viewed, the position of the subject matter on the screen, the placement of real or apparent borders or windows, and the psychological and physiological condition of the spectator.

It is apparent, therefore, that values for φ can be determined only by empirical methods. Fortunately such investigations have been carried out by Hill,[5] particularly for the more critical case of the close-up. Since φ involves so many variables, it will have to be determined empirically for each unusual scene.

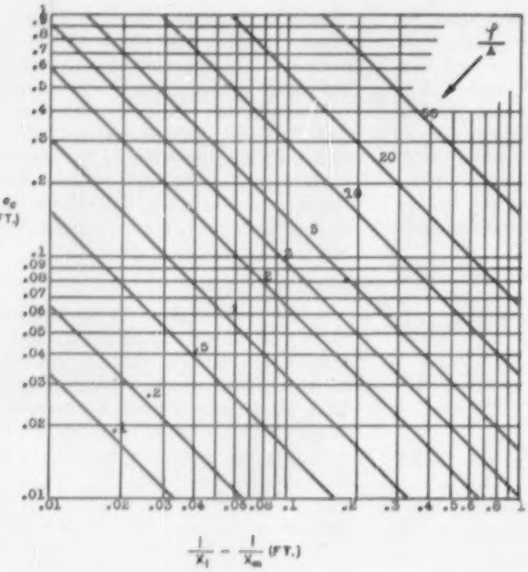

Fig. 5. Camera interaxial graph. Use only with: M = 350; E = 2.1; f_c = 0.083 ft; t_m = e = 0.2 ft.

III. THE MECHANICS OF TRANSMISSION

The mechanics of transmission involve filming, printing and projecting. However printing of 3-D films generally involves no special considerations except perhaps optical enlargement or reduction, both of which are accounted for by the enlargement, E. Likewise there is little variation possible in projecting, for it is standard practice to converge the optical paths of the projectors at the screen. The only real variations generally encountered in transmitting 3-D images are in camera interaxial and convergence. Therefore this section will concern itself only with the mechanics of filming. Later, in Part IV, the results of inaccuracies in printing and projecting, as well as in filming, will be investigated.

Practical Filming Formulas

In Part II the theoretical filming formulas (2.3) and (2.4) were developed, and it was pointed out that certain practical considerations would necessarily modify those theoretical filming formulas. It would be desirable, for instance, to be able to place any plane in the original scene at any predetermined apparent location in the theater. From (2.5) it is seen that A can be effectively controlled only by camera interaxial and convergance, for e, the human interocular, is fixed, M and E, magnification and enlargement, are dictated by film size and screen size, f_c, the focal length of the camera lens, is generally determined by the shot, and φ, the psychophysiological factor, is obtained from empirical data.

The determination of camera interaxial and convergence is guided by two considerations. First, the less the interaxial and convergence are changed from the theoretically correct values given by (2.3) and (2.4), the more the 3-D image will appear like the original scene. Second, camera interaxial and convergence must remain within certain bounds if the separation of point pairs on the screen is not to exceed values limited by the restrictions imposed by the human visual apparatus.

This second consideration requires that camera interaxial and convergence be expressed as a function of the separation of point pairs in order to study the effect of filming practice on point pair separation. This separation, t, is seen from Fig. 4 to equal v − u, and can be shown[6] to be given by

$$t = -MEf_c\left(\frac{e_c}{x_1} - 2\tan\phi\right) \quad (3.1)$$

where the geometric location of the composite image is behind the screen if t is positive.

The maximum positive separation, t_m, must be restricted or else the eyes of the spectator will diverge to an extent which will produce undesirable effects on the spectator.[7] There is evidence to indicate that in viewing the 3-D film the eyes of the average spectator can diverge as much as one degree without creating undue strain.[5] By applying this result to a front row spectator, a value of t_m is obtained.

How t_m influences camera interaxial and convergence separately is best seen by solving (3.1) and (2.5) simultaneously. Then,

$$e_c = \frac{\dfrac{\varphi e}{AMEf_c} + \dfrac{t_m - e}{MEf_c}}{\dfrac{1}{x_1} - \dfrac{1}{x_m}} \quad (3.2)$$

$$\tan\phi = \frac{e_c}{2x_m} + \frac{t_m}{2MEf_c} \quad (3.3)$$

in which x_m is the distance to the farthest plane in the scene.

Equations (3.2) and (3.3) allow the cameraman to make rapid settings of camera interaxial and convergence, while still allowing him to place any object in the scene at any apparent location in the theater. The correct values for camera interaxial and convergence can be obtained almost immediately from graphs, such as those of Figs. 5 and 6. It should be noted that these graphs are shown only as examples and apply only to the specialized case of 16-mm filming with a 1-in. lens, enlargement to 35mm, projection on a 24-ft screen (M = 350), and a conservative maximum separation of point pairs equal to the human interocular.

Filming Procedure

The following filming procedure allows independent placement of any plane in the scene, and, at the same time, results in a simple and rapid determination of camera settings:

(1) Before the shooting begins, values of M and E are determined. If both filming and projection are done in 35mm, E is unity.

(2) Distances to the principal object and to the far plane are measured.

(3) The director decides on the eventual apparent location of the principal object. The factor φ is then known for this viewing case from existing empirical data.

(4) After the desired lens is selected for the shot, a graph, such as that of Fig. 5, is used to determine camera interaxial.

(5) This value of camera interaxial is used in a second graph, such as Fig. 6, to determine camera convergence.

This filming procedure is supplemented by three filming guides, which are obtained from an inspection of (3.2) and (3.3):

(1) Whenever possible, the director's choice of the apparent location of the principal object should approximate its actual location in the original scene with respect to an imaginary screen as far away from the camera as the theater screen is from the average spectator.

(2) The most distant plane should be as far away from the camera as possible.

(3) If e_c obtained from the graph is less than the value of camera interaxial given by (2.3), attempt to:

a. increase the shooting distance;
b. decrease the focal length of the camera lens;
c. decrease the apparent location.

IV. THE ACCURACY OF TRANSMISSION

Because of mechanical, optical and human limitations, errors or inaccuracies will occur during the transmission of the image from scene to screen. To determine the probable extent of such errors is the object of this section with a view toward discovering those critical factors in the transmission system which introduce excessive errors. Since the eventual purpose of investigating the inaccuracies

of transmission is to determine whether such inaccuracies can be handled by the spectator without causing undesirable effects, it is necessary to describe these inaccuracies in a manner which can be related to pertinent information supplied by the field of physiological optics.

Errors or inaccuracies in transmission are of two principle types: (1) intermittent inaccuracies, in which point pairs may exhibit excessive vibratory movement on the screen, resulting in fatigue to the spectator or even diplopia, and (2) steady inaccuracies, in which point pairs may be positioned incorrectly on the screen, resulting in either diplopia or in an apparent location of the composite image other than that intended. These two types of errors will now be investigated, first with regard to the horizontal plane and then with regard to the vertical plane.

Intermittent Errors in the Horizontal Plane

Intermittent errors or inaccuracies are due mainly to the lack of film registration in cameras, printers and projectors, and to vibration of equipment. Such inaccuracies result in intermittent movement of point pairs on the screen. This movement in the horizontal plane will be expressed as the variation in the convergence angle of the eyes, for physiological optics offers valuable information regarding the probable extent to which the spectator can adequately handle variations in this convergence angle.[7] It should be noted that variations in the convergence angle may be simply a mathematical expedient, and it should not be assumed that the eyes necessarily follow the vibratory movement of point pairs on the screen. Nevertheless, even though the variation in the convergence angle is only geometrical, this variation will have physiological effects on the spectator.

The variation in the convergence angle, shown as α in Fig. 4, is expressed as the total derivative of α. It can be shown[6] that the convergence angle is given by

$$\alpha = 2\tan^{-1} \times \left\{ \frac{e}{2s} + \frac{Ee_p}{4s}\left[\frac{f_{cr}}{f_{pr}\tan\theta/_r}\left(\frac{y_1 + \frac{e}{2}}{x_1} - \tan\phi/_r \right) - \frac{f_{cl}}{f_{pl}\tan\theta_l}\left(\frac{y_1 - \frac{e}{2}}{x_1} + \tan\phi_l \right) \right] \right\} \quad (4.1)$$

in which the additional subscripts r and l refer to right and left members of camera or projector pairs. This is necessitated by the fact that at the present there is no unified piece of equipment, and resort is usually made to two conventional cameras and projectors coupled together. For this reason errors in left members, such as the left projector, must be treated independently of errors in right members.

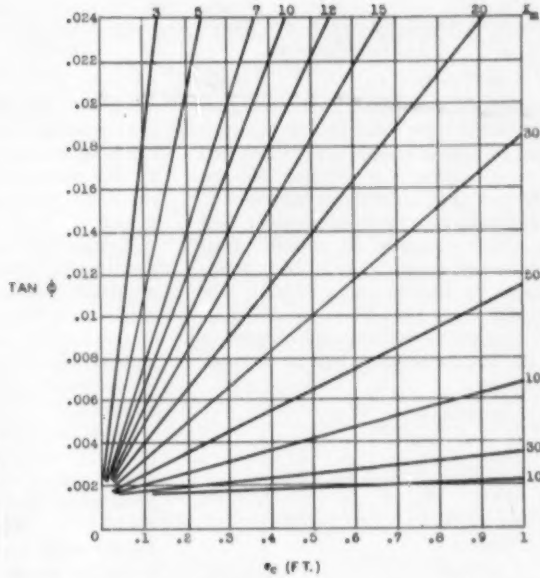

Fig. 6. Camera convergence graph. Use only with: M = 350; E = 2.1; f_c = 0.083 ft; t_m = e = 0.2 ft.

The derivative of α can be greatly simplified by noting the following:

(1) Although the convergence angle is a function of y_1, the lateral displacement of the object in front of the camera, it can be shown that the variation in the convergence angle is a maximum for $y_1 = 0$ (center of the camera field and center of the screen).[6] Thus by confining the study of the convergence angle to the center of the screen, it will be known that acceptable variations of α in this region will certainly be acceptable for the remainder of the field.

(2) It can be assumed that no intermittent variations occur in the spectator-screen distance, the human interocular, the camera and projector interaxials, and focal lengths of all lenses.

By utilizing the foregoing considerations, the variation in the convergence angle can be approximated by

$$\begin{aligned} d\alpha = \frac{MEf_c}{s}\Big[& \left.\begin{aligned} & d\tan\phi_r \\ & + d\tan\phi_l \end{aligned}\right\} \text{filming} \\ & \left.\begin{aligned} & + \left(\frac{e_c}{x_1} - 2\tan\phi\right)\left(\frac{1}{Ew_c}dw_p \right. \\ & \left. + \frac{1}{w_c}dw_c\right) \end{aligned}\right\} \text{printing} \qquad (4.2) \\ & \left.\begin{aligned} & + \frac{1}{\tan\theta}\left(\frac{e_c}{x_1 2} - \tan\phi\right)d\tan\theta_r \\ & + \frac{1}{\tan\theta}\left(\frac{e_c}{2x_1} - \tan\phi\right)d\tan\theta_l \end{aligned}\right\} \text{projecting} \end{aligned}$$

The terms are all additive due to the fact that the errors are independent of each other, and thus the maximum variation in the convergence angle could be the summative effect of the separate errors. The errors are divided into three parts: those that occur during filming, printing and projecting. The printing term should be repeated for each generation of printing.

It should be noted that the intermittent variation of the convergence angle has been attributed only to the lack of film registration in cameras, printers and projectors. If any other factor contributes significantly during transmission to the intermittent movement of point pairs on the screen, these factors should be incorporated in (4.2). For instance, if significant vibration occurs during filming, such vibration should be expressed as a change in the camera convergence angle and added to d tan ϕ.

Later in this section Eq. (4.2) will be applied in an actual example in order to indicate the order of the inaccuracies involved.

Steady Errors in the Horizontal Plane

Mechanical, optical and human errors can also create a steady or constant inaccuracy of point pairs from their intended position on the screen. How long such a steady error will remain on the screen will depend on the cause. If it is due to an incorrect setting of the cameras, the error will last for at least the length of the shot; if the error is due to a misaligned projector, the error will probably last for the entire picture.

Steady errors in the horizontal plane can cause the composite image to appear other than where the director intended. To investigate how the apparent location is affected by steady errors it is necessary to express the total derivative of A with respect to all its significant variables. It can be shown[6] that the apparent location of any point in the x-y theater plane is given by Eq. (4.3) below.

The total derivative of A can be simplified by employing the following assumptions:

(1) The projectors are symmetrically located on either side of the median line normal to the screen.

(2) One member of a pair (arbitrarily the left) is assumed to have the correct or calculated value, and any discrepancy

$$A = \frac{\rho e}{\left\{ e + \frac{Ee_p}{2}\left[\frac{f_{er}}{f_{pr}\tan\theta_r}\left(\frac{y_1 + e_e/2}{x_1} - \tan\phi_r\right) - \frac{f_{el}}{f_{pl}\tan\theta_l}\left(\frac{y_1 - e_e/2}{x_1} + \tan\phi_l\right)\right]\right\}} \tag{4.3}$$

between the members is attributed as an error in the right member. For instance, if the two camera lenses are not matched in focal lengths, it is assumed that the difference is an error in the right lens.

By employing these assumptions, and denoting a change in the apparent location, as well as the steady errors in transmission, by increments in order to distinguish them from intermittent errors, the equation for the effect of steady errors in the horizontal plane can be approximated by

$$\begin{aligned}
\Delta A = \frac{A^2MEf_e}{\varphi e}\Bigg[& \frac{e_e}{x_1^2}\Delta x_1 + \frac{1}{f_e}\left(\frac{y_1 - (e_e/2)}{x_1} + \tan\phi\right)\Delta f_e + \frac{1}{x_1}\Delta e_e + \Delta\tan\phi_r && \text{filming}\\
& + \left(\frac{e_e}{x_1} - 2\tan\phi\right)\left(\frac{1}{Ew_e}\Delta w_p + \frac{1}{w_e}\Delta w_e\right) && \text{printing}\\
& - \frac{1}{f_p}\left(\frac{y_1 - (e_e/2)}{x_1} + \tan\phi\right)\Delta f_{pr} + \frac{1}{\tan\theta}\left(\frac{y_1 - (e_e/2)}{x_1} + \tan\phi\right)\Delta\tan\theta_r\\
& + \frac{1}{e}\left(\frac{e_e}{x_1} - 2\tan\phi\right)\Delta e + \frac{e}{AMEf_e}\Delta\varphi\Bigg] && \text{projecting}
\end{aligned} \tag{4.4}$$

As with the horizontal intermittent errors, the expression for the horizontal steady errors can be divided broadly into the three stations of transmission where most inaccuracies are introduced. If shrinkage occurs in one aspect and not in the other, such shrinkage is best accounted for in the printing term as a difference in film width. Differential shrinkage of film length is considered under steady errors in the vertical plane. Since all the contributing factors are independent, the maximum total error could be the summative effect of the individual errors. However the correct mathematical signs have been retained in front of the terms involving camera and projector lenses in order to emphasize the argument which now follows.

An inspection of (4.4) reveals that a disparity in focal lengths of lens pairs (the right camera lens being longer than the left, for instance) creates an error in apparent location which is a function of y_1, the lateral position of the object in front of the camera. If focal length disparity does occur and corrective measures are not employed, a plane in the physical world is transmitted as a curved surface in the theater. Since y_1 can be of the same order of magnitude as x_1, the error in A can be shown to be significant, particularly at the sides of the screen.

Fortunately it is possible to compensate partially for differences in focal length of camera and projector lens pairs. It can be seen from (4.4) that if the longer lens is kept on the same side (say the left) in both filming and projecting, the errors due to focal length disparity tend to cancel.

Equation (4.4) further reveals the possibility of a simplified uniconvergent filming system in which the total filming convergence is invested in only one of the two cameras. If it is assumed that the left camera has a fixed convergence, it can be shown that (4.3) can be approximated by[6]

$$A = \frac{\rho e}{e + MEf_e\left(\frac{e_e}{x_1} - \tan\phi_r'\right)} \tag{4.5}$$

where ϕ_r' is the right camera convergence in a uniconvergent system. If $\phi_r' = 2\phi$, which for the small angles being considered approximates to $\tan\phi_r' = 2\tan\phi$, then it is noted that (4.5) can be approximated by (2.5).

It is concluded, then, that a system employing a nonconverging left camera will yield results which are similar to those of a system in which both cameras converge symmetrically as long as the convergence of the right camera in the uniconvergent system is twice the convergence of either camera in the biconvergent system.

The possibility of employing the uniconvergent system is mentioned because of the several advantages of such a system. Some of these advantages are: (1) the convergence of only one camera lends itself to mechanical simplicity; (2) the error created by $\Delta\tan\phi_l$ is eliminated; and (3) for camera mounts which employ a rotating mirror to effect camera convergence, the angle through which the mirror is rotated, is that read directly from a graph similar to Fig. 6. This last point results from the fact that the angular change in the reflected light is twice that of the mechanical angular displacement of the mirror.

An Example of Horizontal Errors

So far in this section two formulas have been set forth which relate mechanical, optical and human errors to quantities which have visual significance, namely formulas (4.2) and (4.4). The following example is intended to indicate the magnitude of the horizontal errors involved. The values obtained can then be interpreted according to information supplied by the field of physiological optics and a prediction made of whether the magnitude of the errors involved is visually acceptable.

The values selected for this example are obtained from experience and from manufacturers' data. The values used are indicative only of the order of magnitude, and should not be interpreted as the exact values which might occur in an actual case. This same example with the same values will be used again in this section when a study is made later of the effect of errors in the vertical plane.

The example chosen is one in which the number of errors, their direction and their magnitude are all at a probable maximum, so that if acceptable results obtain in this case, they certainly will in less demanding cases. The example involves the filming of a documentary field scene by a single operator. The requirement of light equipment precludes the use of cameras with registration pins. Therefore two light, spring-loaded cameras are selected in order that the total weight of the equipment, including cameras, films, a base on which to mount the cameras, and tripod, does not exceed 60 lb. The original film is enlarged in an optical printer, and this 35mm master is used to contact print the release prints. Projection is on a 24-ft screen.

The actual computation of the errors involved is shown elsewhere,[6] but the values used and a summary of the errors computed are given in Table I. All lengths are given in feet. The longer lens of lens pairs has been kept on the left. The value of y_1 used was selected to yield the greatest possible error, an error which corresponds to a point at the edge of the screen.

When the values summarized in Table I are substituted in (4.2), the intermittent variation in the convergence angle of the eyes is:

$d\alpha =$	0.00082	right camera	filming
	0.00082	left camera	
	0.000006	optical printer	printing
	0.000003	contact printer	
	0.000028	right projector	projecting
	0.000028	left projector	
	0.00173	radians, or about 6′ of arc	

It has been indicated that even with an intermittent error of this magnitude point pairs will be fused and the composite image will appear steady.[7] However there is no guarantee that the spectator will not exhibit some other undesired effect, such as fatigue; experimentation in the theater will best determine such possibilities.

When the values summarized in Table I are substituted in (4.4), the steady error in apparent location becomes:

ΔA		
= 0.0306	subject distance	filming
+0.1010	camera lens focal length	filming
0.0366	camera inter-axial	filming
0.0128	camera convergence	filming
0.0163	optical printer	printing
−0.1010	projector lens focal length	printing
0.1010	projector convergence	projecting
0.0326	human interocular	projecting
0.0495	psychophysiological factor	projecting
0.2794		

The correct signs for the errors due to disparities of lens pairs are shown for the condition that longer lenses are kept on the left.

It is seen that even for this example in which errors in all the nine principle factors contributing toward a steady error in the horizontal position of point pairs are at a maximum and additive (a highly improbable occurrence), the total error in apparent location of the composite image is only about one-fourth the spectator-screen distance, hardly excessive for such a rigorous transmission case.

Table I. Summary of Values for Horizontal Errors.

		Errors			
		Steady, Δ		Intermittent, d	
	Values	%	Absolute	%	Absolute
Filming					
x_1	10	5	0.5	0	0
y_1	2	—	—	—	—
f_{cr}	0.083	1	0.00083	0	0
e_c	0.12	6	0.0072	0	0
$\tan \phi$	0.0028	9	0.000252	0.25*	0.001
Printing					
E	2.1	—	—	—	—
w_c } optical	0.0342	5	0.00171	0.1*	0.0000342
w' }	0.0724	0	0	0.1*	0.0000724
w' } contact	0.0724	0	0	0	0
w_p }	0.0724	0	0	0.1*	0.0000724
Projecting					
M	350	—	—	—	—
A	0.5	—	—	—	—
s	75	0	0	0	0
f_{pr}	0.36	2	0.0072	0	0
$\tan \theta$	0.02	1	0.0002	0.1*	0.00019
e	0.2	10	0.02	0	0
φ	1.5	10	0.15	0	0

* Per cent lack of registration.
w'—width of inter-stock.

Intermittent Errors in the Vertical Plane

So far in this section consideration has been given only to the accuracy of transmission in the x-y plane. However the limitations of human vision demand that the inaccuracies of transmission should also be restricted in the vertical plane. Such inaccuracies can create intermittent and steady vertical disparities of point pairs, the steady errors being discussed later. Intermittent vertical movement of point pairs can create fatigue and even diplopia, depending on the extent of the movement.

Vertical disparity, or differences in height of homologous points, can be described in a manner related to physiological optics by the difference in elevation angles to homologous points. The elevation angle is shown as μ in Fig. 7, where it applies to the camera, and as β in Fig. 8, where it applies to the spectator.

As with intermittent variations of the convergence angle in the horizontal plane, it should again be emphasized that although intermittent variations of the elevation angle may have a physiological effect on the spectator, his eyes will not necessarily follow the rapid vertical movement of points on the screen.

In Figs. 7 and 8 the same coordinate orientation is employed as that used previously in Part II. Again the x-axis in the filming diagram lies in the plane perpendicular to the effective film plane and along the direction of filming, while the x-axis in the viewing diagram lies in the median plane of the spectator and connects the Cyclopean eye with the center of the screen.

The elevation angle, β, can be shown to be given by the expression

$$\beta = \tan^{-1} \frac{MEf_c \tan \mu}{s} \qquad (4.6)$$

Due to any lack of registration which may occur in cameras, printers and projectors, as well as to vibration of equipment, the elevation angle of either aspect may vary from the value given by (4.6). This intermittent variation is expressed by the total derivative of β with respect to its significant variables. Thus,

$$d\beta = \frac{MEf_c}{s}\Big[d \tan \mu \qquad \text{filming}$$

$$+ \frac{z_1}{x_1}\left(\frac{1}{Eh_c} dh_p + \frac{1}{h_c} dh_c\right) \qquad \text{printing}$$

$$+ \frac{z_1}{x_1 \tan \gamma} d \tan \gamma \Big] \qquad \text{projecting} \qquad (4.7)$$

Equation (4.7) contains the declination angle of either projector, shown as γ in Fig. 9. As before, the contributing factors are independent and could be additive.

Steady Errors in the Vertical Plane

Steady errors can cause a constant difference in height between point pairs. This difference can last for the length of the shot or longer, depending on the cause. The effect on the spectator is to induce one eye to angle upward. This unnatural act may cause either fatigue or diplopia, depending on its magnitude. The steady disparity of homologous points in the vertical plane will not create an error in apparent location, for the mind will not accept the third dimensional percept as a function of vertical disparity, nor will the mind devise an entirely new fourth dimension resulting from this disparity.

The steady error in the elevation

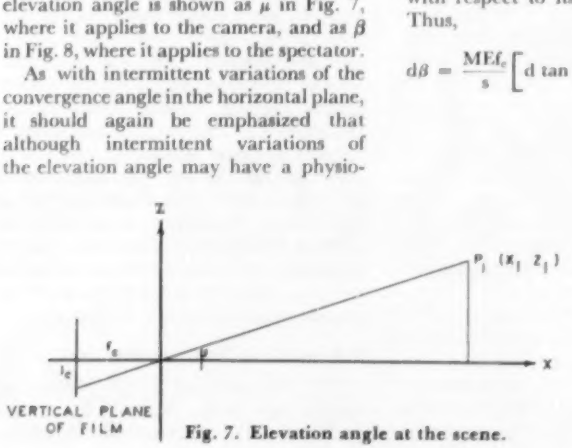

Fig. 7. Elevation angle at the scene.

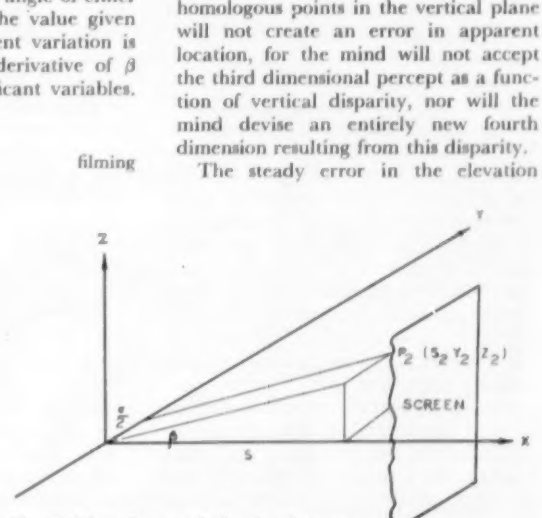

Fig. 8. Elevation angle in the theater.

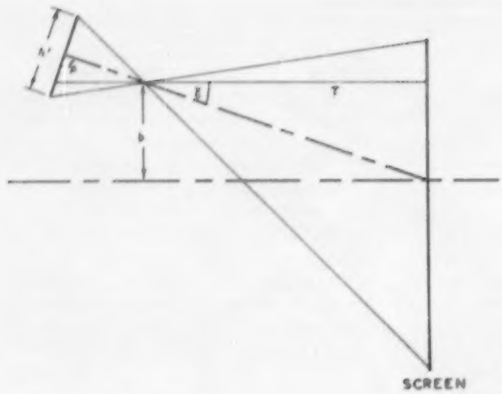

Fig. 9. Elevation and declination of the projector.

angle of either aspect is described by the total derivative of β with respect to all its significantly contributing factors. As with the steady errors in the horizontal plane, steady errors in the vertical plane will be denoted by increments in order to distinguish them from intermittent errors. The steady errors in the vertical plane are given by

$$\begin{aligned}\Delta\beta = \frac{MEf_c}{s}\Bigg[&\frac{z_1}{x_1 f_c}\,\Delta f_c \\ &+ \Delta \tan\mu \Bigg\}\ \text{filming} \\ &+ \frac{z_1}{x_1}\left(\frac{1}{Eh_e}\,\Delta h_p + \frac{1}{h_e}\,\Delta h_e\right)\Big\}\ \text{printing} \\ &- \frac{z_1}{x_1 f_p}\,\Delta f_p \\ &+ \frac{z_1}{x_1 b}\,\Delta b \\ &+ \frac{z_1}{x_1 \tan\gamma}\,\Delta\tan\gamma\Bigg]\Bigg\}\ \text{projecting}\end{aligned} \qquad (4.8)$$

Equation (4.8) contains the elevation or height, b, of the projector above a plane passing through the center of the screen and normal to it, as shown in Fig. 9. As usual, the contributing factors are independent and could therefore be cumulative. However the correct mathematical signs have been retained for the terms involving disparities in focal lengths of lenses in order to emphasize once more the desirability of keeping the longer lens on the same side, say the left.

The errors listed in (4.8) are simply differences between the two aspects, differences which may be introduced during filming, printing or projecting. Therefore in applying (4.8) to an actual case it can be assumed the left member has the correct values, and only the differences between the members need be used in (4.8), these differences being interpreted as errors in the right member.

An Example of Vertical Errors

After the formulas for errors in the horizontal plane were described, an example was employed to indicate the order of magnitude of the factors involved. That same example will be applied now to the two formulas for determining errors in the vertical plane.

As before, it is assumed that longer lenses of lens pairs are kept on the left. Since both $d\beta$ and $\Delta\beta$ increase with increasing z_1, and since it is desired to compute the maximum error possible, the maximum value of z_1 encompassed by the camera lens will be used. This point will then appear at the top of the screen. As before, the computations will not be shown, but the values used and a summary of the errors computed are given in Table II. Again all lengths are in feet.

Table II. Summary of Values for Vertical Errors.

		Errors			
		Steady, Δ		Intermittent, d	
	Values	%	Absolute	%	Absolute
Filming					
x_1	10	—	—	—	—
z_1	1.25	—	—	—	—
f_c	0.083	0.5	0.000415	0	0
$\tan\mu$	0.125	—	—	0.25*	0.000735
axis inclination	—	—	0.00029	0	0
height	—	—	0.00025	0	0
Printing					
E	2.1	—	—	—	—
h_e } optical	0.0245	0.5	0.000123	0.1*	0.0000245
h' } optical	0.0525	0	0	0.1*	0.0000525
h' } contact	0.0525	0	0	0	0
h_p } contact	0.0525	0	0	0.1*	0.0000525
Projecting					
M	350	—	—	—	—
s	75	—	—	—	—
f_p	0.36	1	0.0036	0	0
b	20	0.5	0.1	0	0
$\tan\gamma$	0.20	0.5	0.001	0.1*	0.000145

* Per cent lack of registration.
h′—height of inter-stock.

When the values summarized in Table II are substituted in (4.7), the intermittent variation of the elevation angle of either eye is:

$d\beta$ = 0.000602	camera	filming
0.000250	optical printer	printing
0.000125	contact printer	printing
0.000091	projector	projecting
0.001068	radians, or about 3.5′ of arc	

This value represents the maximum angular variation of either eye for this particular example. The intermittent error in the elevation angle to the other eye could be an equal amount in the opposite direction. There is some theoretical indication that diplopia will not occur for intermittent vertical errors of the order just computed.[7] However no precise experimentation with the 3-D film has been undertaken to determine what value of $d\beta$ causes an undesired effect on the spectator.

When the steady errors in Table II are substituted in (4.8), the steady vertical disparity of a point near the top of the screen from its homologous point is:

$\Delta\beta$ = +0.00102	camera lens	filming
0.00051	camera height	filming
0.00046	camera inclination	filming
0.00102	optical printer	printing
−0.00102	projector lens	projecting
0.00102	projector height	projecting
0.00102	projector declination	projecting
0.00403	radians, or about 14′ of arc	

This value of $\Delta\beta$ represents the maximum steady angular divergence of the eyes in the vertical direction for a spectator seated 75 ft away from the screen. Independent observers have determined that vertical divergence of the eyes must be at least one degree before diplopia occurs.[8,9] Therefore, even for so rigorous a transmission problem as has just been shown, fusion still results. Whether such a value of vertical divergence causes some other undesired effect is a problem which has not been solved specifically for motion-picture conditions.

Tolerances in Transmission

The example used in this section, in conjunction with Eqs. (4.2), (4.4), (4.7) and (4.8), helps to indicate where

in the transmission system particular attention should be paid to tolerances. In general the tolerance of any factor in a system should be such that its effect on the accuracy of that system is of the same order of magnitude as the effect of the other factors. With this in mind the following observations can be made:

(1) If the convention of keeping the longer focal-length lenses on the left is not followed, then camera and projector lens pairs should be kept to within $\frac{1}{4}$ of 1% if the error in A at the edge of the screen created by focal length disparity is to be of the same order of magnitude as the other errors.

(2) The error in reading graphs, such as those of Figs. 5 and 6, has been included as an error in the setting of camera interaxial and convergence. Such an error can be reduced by the use of a computing device, such as the one developed by the Motion Picture Research Council.[5]

(3) Errors as large as 5% can be tolerated in the measurement of the camera-to-object distance, and in the setting of camera interaxial and convergence.

(4) The optic axes of the cameras should have the same inclination within 2′ of arc.

(5) The error due to camera registration could be minimized by the use of shorter focal-length lenses.

(6) In general, the lack of registration in the cameras is a greater contributing factor toward the unsteadiness of the two aspects than is the lack of registration in the projectors, even if the film width is the same and the per cent lack of registration is the same in both filming and projecting.

(7) Errors in printing are relatively insignificant.

(8) The errors in projector convergence and declination should be kept to within $\frac{1}{2}$ of 1%.

(9) Because the human visual apparatus can handle a greater degree of intermittent movement of point pairs in the horizontal direction than in the vertical direction,[7] film registration should be more exact in the vertical direction.

(10) All steady errors increase around the borders of the screen.

(11) All errors increase for close-ups.

(12) Errors are less acute for spectators seated farther from the screen.

(13) A scene shot in 16mm and projected in 16mm on a given size screen will appear stereoscopically identical to the same scene shot in 16mm but projected in 35mm on the same size screen.

Acknowledgments

This paper is an abridged portion of a thesis for an M.A. degree in Cinema obtained from the University of Southern California. The author is pleased to acknowledge the guidance of his thesis committee: Wilbur T. Blume, Chairman; Nicholas Rose; Paul A. White. The encouragement of Lester F. Beck, Head of the Department of Cinema, was also invaluable. The many suggestions offered by Armin J. Hill during the preparation of this paper are greatly appreciated.

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Recent Developments in Feedback Lateral Disk Recorder

ABSTRACT

By C. C. DAVIS

The Westrex 2B Recorder has an improved spring-hinge arrangement. Previously there had been a tendency toward a shift in the operating axis of the cantilever spring at frequencies above 10 kc, causing sharp dips in the recorded frequency response in this range. The recent interest in recording higher frequencies has resulted in a modification which has largely eliminated these "holes." The modification consists of extending the body of the coil form to the normal rotational axis of the hinge. This fin-shaped extension revolves about an axis which coincides with the axis of the spring one-third the distance from the spring clamp to the coil form. It is embedded at this point in a compliant material which allows the hinge to flex normally but discourages rotation about any but the intended axis.

Stylus-heating facilities have been provided in the 2B Recorder. These consist of two small terminals to which may be attached a simple heater coil energized with 6 v from an a-c source. The heater coils are designed to slide over the stylus and are held in place by the natural spring tension of their leads.

Acetate playbacks of L.P. recordings at 10 kc and at a 6-in. diameter show as much as 10-db improvement in noise and a gain of 16 db in signal, when cut with heated sharp styli as compared to unheated dulled-edged styli intended for cold use. The temperature at the stylus tip is in the neighborhood of 350 F and can be measured with waxes having known melting points. With the hot-stylus attachment the coil form is modified to use tapered-shank styli and a removal tool has been designed for their ready installation and removal.

The advance-ball assembly has been redesigned to permit positioning the advance ball directly ahead of the recording area and it is provided with an additional lateral adjustment for tracking exactly in line with the material to be removed in order to prevent scars remaining on the record if a particle of dirt collects under the advance ball.

A new amplifier has been designed to operate with the 2B Recorder.

The high and low frequencies may be increased or decreased several decibels by adjustment of the feedback control. When adjusted to normal the system is flat from amplifier input to reproducer output from 30 cycles to 11 kc. A dip of about 4 db centers at 15 kc, beyond which a long rise occurs extending to approximately 28 kc where the level exceeds that of the midrange. The feedback has little control beyond 11 kc and the peak at 28 kc appears solely due to a secondary mechanical resonance. However, this rise in response serves a useful purpose because the system may be equalized to a point well beyond 20 kc by the insertion of a single equalizer to boost the level in the 15-kc range.

Records made with the new recorder and its associated amplifier show low intermodulation and unusually accurate reproduction of square waves.

Abstract of a paper presented on October 20, 1954, at the Society's Convention at Los Angeles by C. C. Davis, Westrex Corp., 6601 Romaine St., Hollywood 38, and published in *J. Audio Eng. Soc.*, 2: Oct. 1954.

Wide Screens in Drive-in Theaters

By RALPH H. HEACOCK

CinemaScope (or any of the other wide-screen, multiple-channel sound, new techniques) presents three important problems to the drive-in theater. The first is a very wide screen. The second is a suitable light source which can provide enough light to acceptably illuminate the wide screen. The third is the possible use of multiple-channel sound. These problems and their practical solution in currently operating drive-in theaters are briefly discussed.

The Problems of a Wide Screen

Last year marked the introduction and widespread use of the wide screen in indoor theaters. Although there may be some question in the minds of some exhibitors relative to the use of multiple-channel sound, apparently most exhibitors agree that the wide screen is one thing that is immediately noticed and receives favorable comment from the theater patrons. Because of this broad acceptance of the wide screen in indoor theaters, the past season has marked the introduction of the wide screen in the drive-in theater.

Drive-in theater screens for use with the conventional 1.33 to 1 aspect ratio pictures have varied in width up to about 70 ft. During the past season the width of drive-in theater screens have very materially increased. The Westbury Drive-In Theatre at Westbury, Long Island, was built during the past season, with a capacity for about 2,000 cars. The screen, seen in Fig. 1, is curved and is 124-ft wide. When a CinemaScope picture is projected it overshoots the screen on each side by about one foot, and it completely fills the screen from top to bottom. This gigantic picture is simply standing out in the sky and all 2,000 of the cars in the theater have an unobstructed view. When a conventional picture is projected, it fills the screen from top to bottom, and the width is somewhat reduced in size.

Figure 2 shows the screen at the Belmont Auto Drive-In Theatre near Dayton, Ohio. This screen is about 110-ft wide and is flat. Here again the CinemaScope picture completely fills the screen, while the conventional picture runs the full height of the screen but not the full width.

It is very interesting to note that both of these screen surfaces are of a white diffusive material. Many who have compared the screen image in these theaters with that obtained on a silver screen feel that both color contrast and color balance are better on a white screen. Some have commented that light distribution on the flat screen is highly satisfactory, and that there apparently is no serious fall-off in screen brilliance.

Recently a screen coating material has been developed which is a real vinyl plastic material (not merely a vinyl base). This type of material was used to "moth ball" the fleet and the B-29's during and after the war. This material has been pigmented so that a mirror coat is sprayed on to the screen surface, which is then followed by a top coat which is brilliantly white and diffusive. Cracks between panels of the existing screen are sprayed with a coat of the mirror material, and are then taped and resprayed so that the tape becomes an integral part of the screen imbedded right in the mirror coat. The end result is that a screen surface is obtained which has practically the same reflectance as a high-grade, indoor, white, diffusive screen. In addition, the material has been formulated to be highly weather-resistant. This material should be of great help in establishing high quality, high reflecting, diffusive, white screens for CinemaScope use in outdoor theaters.

Light Source

The second problem in the operation of drive-in theaters of this type is a suitable light source which can provide enough light to illuminate acceptably these very large screens. In both of the outdoor theaters described, a very dependable arc lamp is employed. The same arc lamp may be employed for use with either the 10mm Standard, 11mm Standard, or the 10mm Hitex carbon. A precision-made 16-in. diameter glass reflector is employed which accurately focuses the positive carbon crater on the projector aperture. The screen end of the arc lamp is equipped with a tilted, heat-reflecting, dichroic reflector. This reflector removes about 40% of the heat from the light beam, while it cuts down visible rays by only 6 to 8%. From a practical viewpoint, this slight decrease in light is of little importance. A group of about half a dozen experienced engineers was gathered in one of our experimental projection rooms, and after dropping the heat reflector into the light beam, and then removing it several times, all the engineers agreed that they could not tell,

Presented on October 21, 1954, at the Society's Convention at Los Angeles, by Ralph H. Heacock, Radio Corp. of America, Front and Cooper Sts., Camden 2, N.J.
(This paper was received on October 11, 1954.)

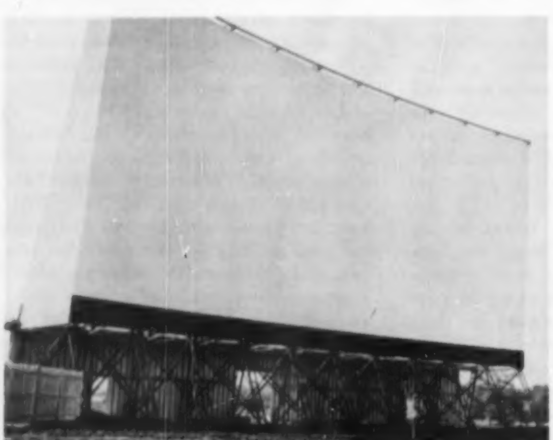

Fig. 1. 124-ft curved screen, Westbury Drive-In Theatre.

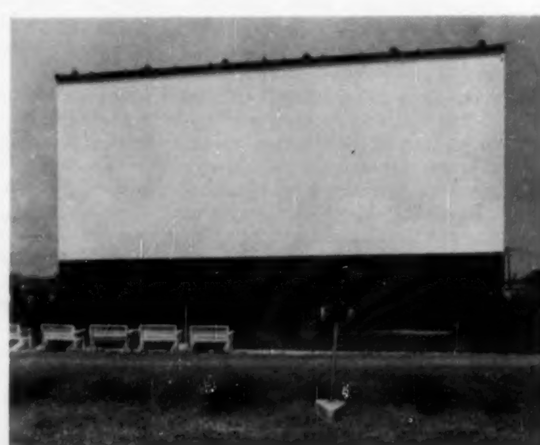

Fig. 2. 110-ft flat screen, Belmont Auto Drive-In Theatre.

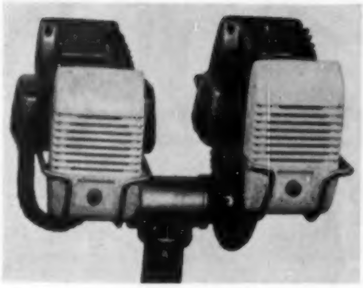

Fig. 3. Two separate speaker installations, Belmont Drive-In Theatre.

with any accuracy, whether the heat reflector was in or out of the light beam. This dichroic reflector is kept cool by a constant flow of air from a small blower.

Multiple-Channel Sound

The past season has marked the introduction of multiple-channel sound in the drive-in theater. Figure 3 shows a typical speaker post in the Belmont Auto Drive-In. Two junction boxes and four drive-in theater speakers are mounted on each post so that each car is equipped with both a righthand and lefthand speaker. Four-track magnetic recordings of a conventional CinemaScope print are resolved into two-channel sound in the following manner. Sound for the left side of the screen is impressed on the lefthand speaker, while that for the right side goes to the righthand speaker. Sound for the center of the screen is divided equally and impressed simultaneously on both the righthand and lefthand speakers, so that the ear interprets the volume level to be the same as that for the sound already coming from each side of the screen. The sound effects track is divided in a similar manner.

A few years ago many of us felt that it might be impractical to attempt to introduce stereophonic sound in drive-in theaters. Because of this, we were extremely careful in our preliminary tests to be sure that the directional effect of this two-channel stereophonic sound was really effective. Since both of the speakers in the car subtend a very much larger angle at the viewer's ears than is the case in a conventional indoor theater, the directional effect is materially enhanced. One of our main concerns was that this enhancement might result in a lack of naturalness. Actual operating tests, however, have convinced us that the effect on the average patron is highly satisfactory.

The second important advantage of two speakers in one car is that obtained by the spatial effect of multiple-sound sources. This improvement has been so great that at the Belmont Auto Drive-In both speakers run continuously even on single-channel sound transmission from a conventional single-track print.

Comparative tests of both two-speaker and three-speaker single units were carried on, and it was our conclusion that the two-speaker unit in a single housing was, in general, about as satisfactory as the three-speaker unit. Since the three-speaker unit is generally driven by three separate channels, this means that three complete separate channels of sound amplification and sound distribution must be employed. Because of the elimination of a complete channel of amplification and distribution, either the double-speaker unit or the two separate speakers may be a more practical method of operation than the three-channel, three-speaker setup.

The double-speaker single unit is admittedly less cumbersome to handle, but it does not have as marked a directional effect on stereophonic sound as do the two separate speakers.

This paper has been presented primarily to outline some of the operational features of CinemaScope prints in drive-in theaters. No doubt, there are many other points of interest which have come to the attention of other members of the Society, but it is believed that the introduction of very wide screens, suitable light sources and the possible use of multiple-channel sound, as typified by the two drive-in theaters mentioned, may be of greatest general interest to the Society.

Television Studio Lighting Committee Report

By H. M. GURIN, *Committee Chairman*

The Television Studio Lighting Committee was formed in January 1950. Almost immediately, work was initiated on the preparation of a lighting terminology. Published below are the partial results of this labor.

The Committee's intent was not to issue an all-inclusive glossary, but rather to define the most common and important terms so that the people in the field could readily converse with one another without the confusion resulting from individual interpretations.

The ten definitions presented here represent the results of a major collective effort. They were drafted by the Television Studio Lighting Subcommittee on Nomenclature, reviewed by the Television Studio Lighting and Motion-Picture Studio Lighting Committees, circulated for comment to practically all the television broadcasting stations in June 1954 and approved in their present form by this Committee on November 18, 1954.

This is by no means the last word on nomenclature. The Committee intends to continue this very important activity and welcomes your suggestions and comments on the terms already defined and terms you would like to have defined.

TELEVISION STUDIO LIGHTING NOMENCLATURE

1 • **High Key Lighting** • A type of lighting which, applied to a scene, results in a picture having graduations falling primarily between gray and white; dark grays and blacks are present but in very limited areas.

2 • **Low Key Lighting** • A type of lighting which, applied to a scene, results in a picture having graduations from middle gray to black with comparatively limited areas of light grays and whites.

3 • **Key Light** • The apparent principal source of directional illumination falling upon a subject or area.

4 • **Base Light** • Uniform, diffuse illumination, approaching a shadowless condition, sufficient for a television picture of technical acceptability, and which may be supplemented by other lighting.

5 • **Fill Light** • Supplementary illumination to reduce shadows or contrast range.

6 • **Cross Light** • Equal illumination in front of the subject from two directions at substantially equal and opposite angles with the optical axis of the camera and a horizontal plane.

7 • **Back Light** • Illumination from behind the subject in a direction substantially parallel to a vertical plane through the optical axis of the camera.

8 • **Side Back Light** • Illumination from behind the subject in a direction not parallel to a vertical plane through the optical axis of the camera.

9 • **Eye Light** • Illumination on a person to produce a specular reflection from the eyes (and teeth) without adding a significant increase in light to the subject.

10 • **Set Light** • Separate illumination of background or set other than that provided for principal subjects or areas which may be composed of items 3 to 8 above.

Submitted on January 4, 1955, by H. M. Gurin, National Broadcasting Co., 30 Rockefeller Plaza, New York 20.

news and reports

77th Convention Program and Hotel

The sessions are developing rapidly now with these special subject leaders:

For Television: William P. Kusack, Station WBKB, 20 N. Wacker Dr., Chicago 6, Ill.

For High-Speed Photography: Richard O. Painter, 738 E. Liberty, Milford, Mich.

For Screen-Brightness Symposium: Fred J. Kolb, Jr., Manufacturing Experiments Div., Bldg. 35, Kodak Park, Rochester 4, N.Y.

For Nontheatrical Motion-Picture Papers: John W. Ditamore, 822 N. Grant St., West Lafayette, Ind.

For any worthy subject: This Convention will not be merely the special subjects noted. There are to be laboratory processing, production and sound papers. Do not hesitate to advise now by wire, telephone or air mail: C. E. Heppberger, *Program Chairman*, 231 N. Mill St., Naperville, Ill. If your paper, or a worthy one you know about, is to be shown in the Advance Program in the March *Journal*, an Author's Form and abstract must reach the Program Chairman before the end of this month. If in doubt, call any one of the Papers Committee Vice-Chairmen, p. 39 of the January 1955 *Journal*, or a member of the Papers Committee, p. 328 of the April 1954 *Journal*.

It is expected that the respective engineering committee members will give special support to Messrs. Painter and Kolb.

Mr. Ditamore's part of the program is a new development for this Convention, with these committee members:

Herbert E. Farmer
John Flory
Neal G. Keehn
Kenneth M. Mason
Malcolm G. Townsley
Henry Ushijima

Equipment and services exhibits will be a part of the Convention. Specifications and cost information are available from the Exhibit Chairman, George L. Oakley, c/o Professional and Industrial Equipment Sales, Bell & Howell Co., 7100 McCormick Rd., Chicago 45, Ill.

The Drake is the hotel for the 77th Convention. Rates and advice about reservations will accompany the postal notice about the Convention, to be mailed to all members later this month. The sooner the better: advise Mr. Jay S. Wallace, Reservation Manager, The Drake, Lake Shore Drive & Upper Michigan Ave., Chicago 11, Ill.

Advise what accommodations you would like and *when you will reach Chicago and when depart.* The rates per day are:

Singles: $7.50; $8.00; $8.50; $9.00; $10.50; $11.00; $12.00; $14.00.

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Suites: (parlor and one bedroom) $23.00; $25.00; $29.00; $30.00; $42.00, and up.

engineering activities

Committee Meeting

The Film Projection Practice Committee met on January 11, 1955, to review the comments received on the first draft of a proposed revision of Z22.35-1947, 16-Tooth 35mm Motion-Picture Projector Sprockets. A full discussion was held and a basis was laid for the preparation of a second draft which should be in the hands of committee members early in February. While this revised standard does not include the sprockets used in conjunction with the CinemaScope process, it does otherwise bring the 1947 standard up to date. In addition, it now includes a section defining the various picture projection sprockets with respect to their function in the projector.

Standards in Process

1. 35mm Motion-Picture Alternate Standard for Positive Raw Stock, SMPTE 772, (CinemaScope film).

2. Revision of American Standard, Dimensions for 35mm Motion-Picture Negative Raw Stock, Z22.34-1949, SMPTE 774.

These two standards are being reviewed by the Film Dimensions Committee. Second drafts of these proposals are now being prepared to correct the faults uncovered in the initial review.

3. Revision of American Standard, Projection Lenses for Motion Picture Theaters, Z22.28-1946, SMPTE 726.

Published in the September 1954 *Journal* for trial and comment and is now being reviewed by ASA Sectional Committee, PH22.

4. Revision of American Standard, 16-Tooth 35mm Motion-Picture Projector Sprockets, Z22.35-1947, SMPTE 791.

See above note on Film Projection Practice Committee meeting.

5. Revision of American Standard, Dimensions for Theater Projection Screens, Z22.29-1948, SMPTE 777.

The Film Projection Practice Committee proposes to limit the 1948 standard until conditions warrant the preparation of a new standard embodying the wide screens. This standard is now being reviewed by the Standards Committee.

6. Proposed American Standard, Screen Brightness of 16mm Laboratory Review Rooms, PH22.100, SMPTE 737.

Published in the January 1955 *Journal* for a three-month period of trial and comment.

7. Revision of American Standard, Picture Printer Aperture for Contact Printing 16mm Positive from 16mm Negative, Z22.48-1946, SMPTE 795.

Approved by the Laboratory Practice Committee and is now being reviewed by the Standards Committee.

8. Reaffirmation of American Standard, Printer Aperture Dimensions for Contact Printing 16mm Reversal and Color Reversal Duplicate Prints, Z22.49-1946.

Approved by the following committees: Laboratory Practice, Standards, PH22 and PSB. It is presently before the American Standards Association's Board of Review. Approval of reaffirmation action is expected shortly.

9. Revision of American Standard, Nomenclature for Motion-Picture Film Used in Studios and Processing Laboratories, Z22.56-1947.

The Laboratory Practice Committee is now reviewing new lists of laboratory terms prior to revising this standard.

10. Revision of American Standard, 16mm Film Perforated One Edge — Usage in Camera, Z22.15-1946, SMPTE 671.

11. Revision of American Standard, 16mm Film Perforated One Edge — Usage in Projector, Z22.16-1947.

Above two standards published in the September 1954 *Journal* for trial and comment and are now being reviewed by ASA Sectional Committee, PH22.

12. Revision of American Standard, Intermodulation Tests, 16mm Variable-Density Photographic Sound, Z22.51-1946, SMPTE 816.

Under review by the Sound Committee.

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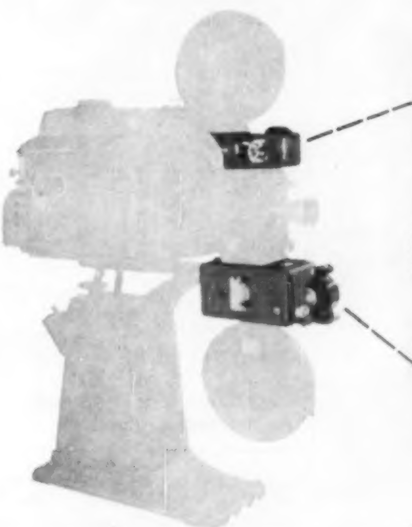

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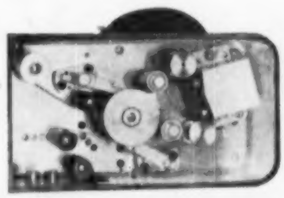

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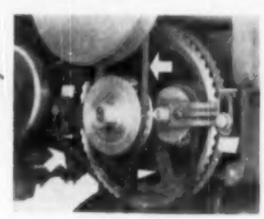

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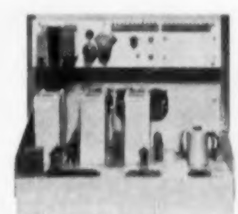

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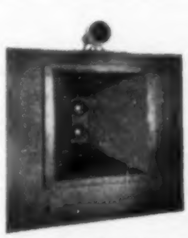

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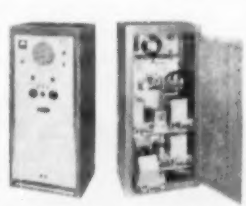

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13. Revision of American Standard, 16mm Sound-Focusing Test Film, Z22.42-1946.

14. Revision of American Standard, 16mm 400-Cycle Signal-Level Test Film, Z22.-45-1946.

15. Revision of American Standard, 16mm Buzz-Track Test Film, Z22.57-1947.

16. Proposed American Standard, 35mm Magnetic Azimuth Alignment Test Film, PH22.99.

Above four standards approved by the following committees: Sound, Standards, PH22 and PSB are presently before the American Standards Association's Board of Review. ASA approval is expected shortly.

17. Revision of American Standard, Photographic Sound Record on 16mm Prints, Z22.41-1946, SMPTE 760.

Approved by the Laboratory Practice and Sound Committees. Further processing is awaiting approval of this standard by the 16 & 8mm Motion Picture Committee.

18. Proposed American Standard, Magnetic Coating of 8mm Motion-Picture Film, PH22.88, SMPTE 756.

Approved by the Magnetic Recording Subcommittee, Sound and Standards Committees and will be published for trial and comment shortly.

19. Proposed American Standard, 200-Mil Magnetic Sound Record on 16mm Film, Perforated One Edge, PH22.97, SMPTE 713.

Approved by the Magnetic Recording Subcommittee and the Sound Committee and will shortly be reviewed by the Standards Committee.

20. Proposed American Standard, 35mm Magnetic Flutter Test Film, PH22.98.

Approved by the Magnetic Recording Subcommittee, the Sound and Standards Committees and is now being reviewed by PH22.

21. Proposed American Standard, Magnetic Coating, 16mm Film Perforated Along Both Edges, SMPTE 758.

Approved by the Magnetic Recording Subcommittee and the Sound Committee and is now being reviewed by the Standards Committee.

22. Proposed SMPTE Recommended Practice, Magnetic Coating, 16mm Magnetic-Photographic Sound Record, SMPTE 752.

Approved by the Magnetic Recording Subcommittee and now under review by the Sound Committee.

23. Proposed American Standard, Separation of Picture and Magnetic Sound on 16mm Film, SMPTE 793.

Being considered by the Magnetic Recording Subcommittee.

Copies of any of the above proposals containing SMPTE numbers may be obtained upon written request.—*Henry Kogel*, Staff Engineer.

Correction of a Proposed American Standard

Proposed American Standard, 35mm Magnetic Flutter Test Film, PH22.98, was published in the February 1954 *Journal* for a three-month period of trial and comment. A phrase, "at any rate," was omitted by error from section 2.6 and consequently, the published version of the standard differed from the draft approved by the Magnetic Recording Subcommittee and the Sound and Standards Committees.

Section 2.6 should read as follows:

2.6 The total rms flutter of the sound recorder shall not exceed 0.1% and the flutter amplitude at any rate shall not exceed 0.05% (as defined in American Standard Z57.1-1954, Method of Determining Flutter Content of Sound Recorders and Reproducers).

It is intended to continue the processing of this standard in ASA Sectional Committee PH22 with section 2.6 specified as above. If there are any comments on this specification of the standard, they should be directed to Henry Kogel, Staff Engineer. —*H.K.*

An Index to American Standards on Cinematography, as of September 1954, and superseding the previous issue of February 1953, is available upon request to SMPTE headquarters. The Standards themselves may be purchased from the American Standards Assn., 70 E. 45 St., New York 17.

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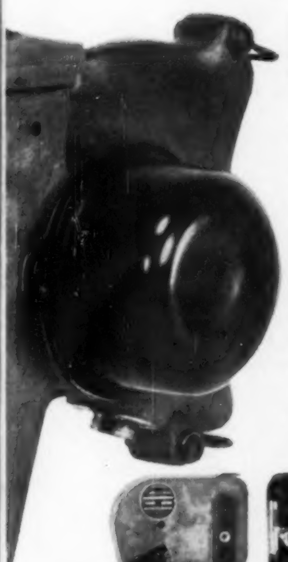

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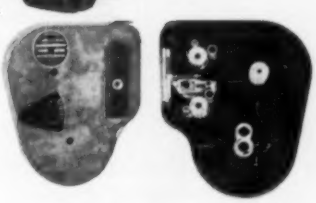
Camera is equipped with 1 each 35mm Baltar lens, 1 each 75mm Baltar lens and 1 each 6" telephoto lens and takes standard Mitchell slide filters. An eye level view finder is provided with fields for the three integral lenses.

Camera is driven by a high speed universal electric motor of the governor-controlled type for operation at 16, 24 or 32 frames per second. Shutter is of the 170° rotary type, counter-weighted and dynamically balanced. Camera will operate from any fixed or portable power supply.

The magazine is of the latest displacement type, reducing weight and size. It holds 200 feet of film and contains the complete film movement mechanism with the dual pilot pin registration unit of the Mitchell type.



The fitted carrying case holds the complete unit, camera, magazine, spare lenses, film and accessories.

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Because of the unusual nature of this truly sensational offer our usual open account terms do not apply. Payment for the full amount must accompany order. (California buyers add 3% sales tax.)

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section reports

The regular meeting of the **Pacific Coast Section** was held on Tuesday, January 11, 1955, in the new NBC Color-Television Studio at Burbank, Calif. The attendance was limited to SMPTE members and guests of the American Society of Cinematographers. A total of 400 persons was present.

Thomas W. Sarnoff, Director of Production and Business Affairs, NBC Hollywood, gave an introductory address. He expressed optimism for the growth of color telecasting and reception during the coming year, and discussed NBC's plans for extensive expansion in this direction.

Gordon Strang, Construction Superintendent, Engineering Dept., NBC New York, discussed architectural considerations in the design of the new color-television studio.

John Lake, Project Engineer, Audio-Video Engineering Dept., NBC New York, reviewed the electrical considerations involved in the design of the color-television studio.

J. R. DeBaun, Technical Supervisor of Burbank Studios, NBC Hollywood, presented the operational aspects of color television. Members of his staff demonstrated the alignment and balancing of the color-TV pickup equipment including cameras and electronic equipment. As the adjustments were described and made, the resultant television signal and the picture as picked up by the camera were shown on monitors throughout the auditorium and on the large projection color-television screen. The formal part of the program was followed by a tour of the complete color-television facilities of this new studio with continuous demonstrations of both the film and the live facilities.

The Pacific Coast Section greatly appreciated the hospitality shown by NBC and their generosity in providing such an extensive demonstration of their new facilities. Particular appreciation is also due the eighteen members of the NBC Burbank technical staff who voluntarily gave of their time to provide the interesting and informative demonstrations.—*E. W. Templin*, Secretary-Treasurer, Pacific Coast Section, c/o Westrex Corp., 6601 Romaine St., Hollywood 38.

The Central Section held its first 1955 meeting on January 17 at the Western Society of Engineers Auditorium.

A very timely subject was covered in excellent fashion by R. E. Putman of General Electric Co. in a paper, "The Continuous Film Projector and Flying-Spot Scanner for Television." This new continuous 16mm television projector and its application to color-film projection on television were described in detail, including color slides. About 65 attended the meeting.

At the pre-meeting gathering of the officers and Board of Managers, preliminary plans for the 77th Semiannual Convention in Chicago were discussed. A meeting of the Nontheatrical Motion-Picture Papers Committee headed by John Ditamore of Purdue University, was also held in conjunction with the Managers' meeting.—*K. M. Mason*, Secretary-Treasurer, c/o Eastman Kodak Co., 137 N. Wabash Ave., Chicago 2.

New Editor, Journal of the Audio Engineering Society

Dr. Vincent Salmon, manager of Stanford Research Institute's sonics section, has been appointed editor of the *Journal of the Audio Engineering Society*. He succeeds Lewis S. Goodfriend, now editor of *Noise Control* published by the Acoustical Society of America.

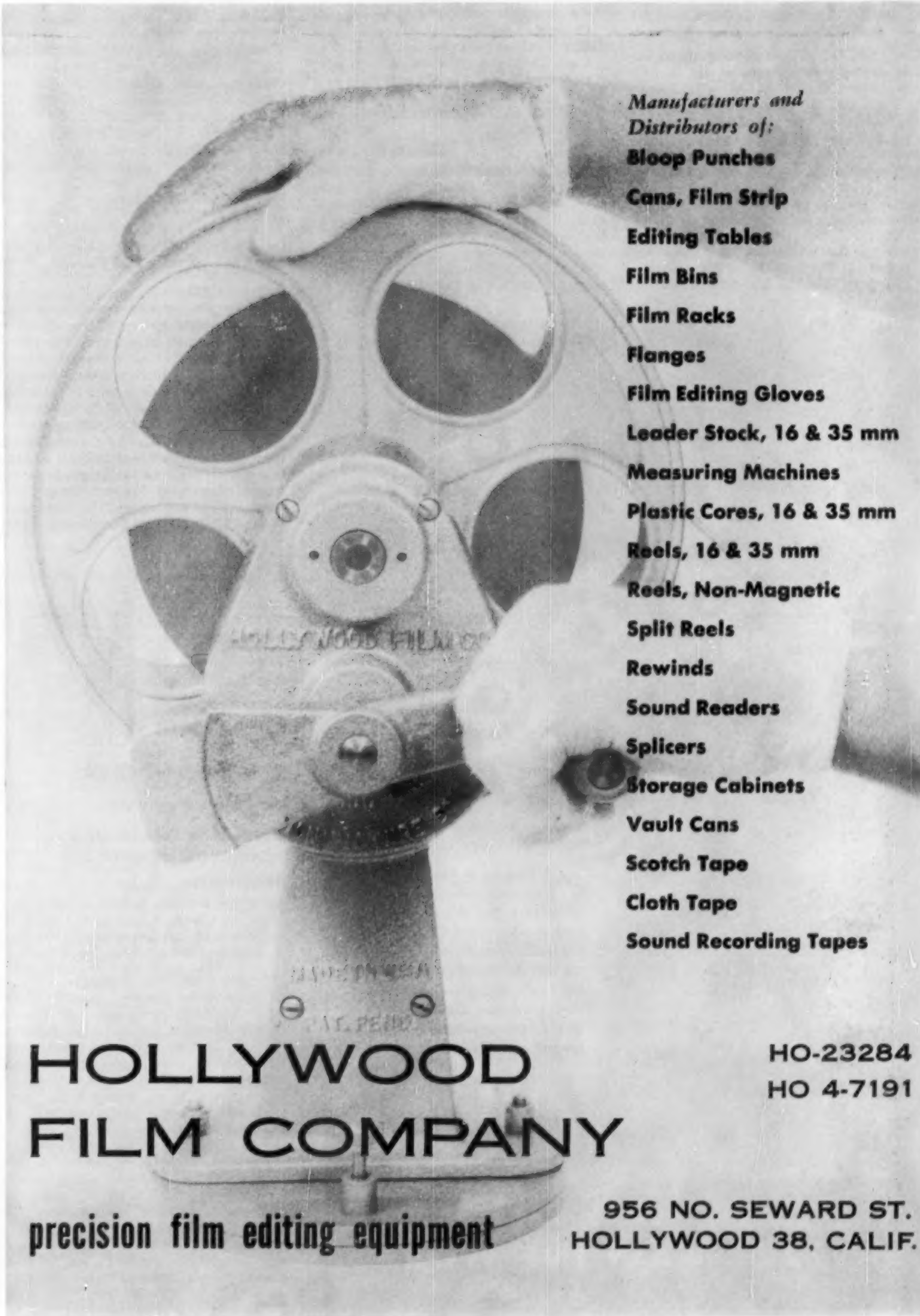
The *AES Journal* deals with advancements in techniques and instruments for high-fidelity recording and reproduction of sound, in studio acoustics, audio components and measuring gear, public address and stereophonic sound systems design and in electronic musical instruments.

Before joining Stanford Research Institute in 1949, Dr. Salmon headed research and development at Jensen Radio Manufacturing Co., Chicago, where he worked on horn theory, multiple-source loudspeaker units and the design of devices used in radar countermeasures. In 1946 he received the biennial award of the Acoustical Society of America for the invention of a new family of horns.

Program of the Annual Meeting of the Inter-Society Color Council

"Control of Moods and Atmosphere" by Richard Kelly, Lighting Designer and Consultant Architect

Dr. Alfred N. Goldsmith, an Eminent Member of Eta Kappa Nu



exact sciences and the psychological and dramatic factors. The scientific fundamentals are reviewed with the assistance of

Program of the Annual Meeting of the Inter-Society Color Council

The Council's 24th Annual Meeting will be held in the Skytop Room at the Statler Hotel, New York City, on Wednesday, April 6, 1955. The morning session will be comprised of reports of the subcommittees of the Problems Committee and the annual business meeting. The afternoon and evening sessions are being planned by a committee of the Illuminating Engineering Society. During the afternoon four presentations are being arranged as follows:

"How You See Colors" by Dr. Robert W. Burnham, Research Psychologist, Eastman Kodak Co.

"Control of Moods and Atmosphere" by Richard Kelly, Lighting Designer and Consultant Architect

"Color Timing in Merchandising" by Mrs. Helen D. Taylor, Director of the Color Bureau, Tanners' Council of America

"Color at Work" by Prof. Edward Carswell, School of Architecture, University of Toronto

In the evening a banquet will be held in the Skytop Room at the Statler and the speaker, Ralph M. Evans, will give his lecture "Creative Directions in Color Photography." Further details on this meeting may be obtained by writing Ralph M. Evans, Secretary of the Inter-Society Color Council, Color Technology Div., Bldg. 65, Eastman Kodak Co., Rochester 4, N.Y.

Dr. Alfred N. Goldsmith, an Eminent Member of Eta Kappa Nu

The electrical engineering honor society, Eta Kappa Nu, on January 31 awarded the grade of Eminent Member to Dr. Alfred N. Goldsmith, making him one of twenty now so honored on a list which includes Lee de Forest and V. K. Zworykin from the electronic field. Dr. Goldsmith is a Past President of the SMPTE, inventor, long well known as a consulting engineer, and Editor Emeritus of the Institute of Radio Engineers.

Amateur Cinema League Termination

An overwhelming vote of the Amateur Cinema League's membership has joined its roster with that of the Motion Picture Division of the Photographic Society of America. *Movie Makers*, the ACL monthly magazine, is being discontinued. The coverage of amateur cinema photography is being increased in the *PSA Journal*. Annual competitions and award systems of both organizations will be continued in an expanded member-service program of PSA's Motion Picture Division. The move adds about 2,500 to the PSA membership roster.

books reviewed

Lighting for Color and Form Principles, Equipment, and Applications

By Rollo Gillespie Williams. Published (1954) by Pitman Publishing Co., 2 W. 45 St., New York 36. v-xvi + 340 pp. 133 illus. + 4 color plates. 6 × 9 in. Price $8.50.

At any other time, it would be appropriate to review this book in terms of the author's intended audience, which is large, indeed, covering the architect, scientist, designer, lighting technician, artist, engineer, display expert, photographer and contractor. Now, however, the reviewer can be pardoned if he examines the book solely with respect to color television.

The author has endeavored to bring together a number of somewhat different, yet related, branches of knowledge concerning lighting principles and practices. He covers the fields of display, stage and photographic interior lighting, and provides a good deal of information on exterior lighting. The point of view is that of a creative, imaginative architect; and, to some extent, the architectural theme dominates the book.

There is a nice balance between the

exact sciences and the psychological and dramatic factors. The scientific fundamentals are reviewed with the assistance of conventional mathematics, chromaticity plots and other accepted devices in a simple and very understandable manner, with no attempt to treat them in encyclopedic detail. The aesthetic factors are also treated in a practical manner, with no resort to esoteric terms.

It is disappointing to find that only eight pages are devoted to the combined subjects of photographic, motion-picture and television studio lighting. In one sense, this is consistent with the author's thesis that the several branches of lighting knowledge are related by a common bond, so that the brief coverage merely implies that there is not much difference between this and any other form of lighting. Certainly, more information is given than the mere page count would indicate. However, 34 pages are devoted to architectural lighting.

A book of such wide scope is, for the specialist technician, at best a review source. The main field of interest may fall at executive, management level where broad coverage is of more interest than detail, and where a knowledge of what has been done in related fields may contribute to imaginative planning. *Bernard D. Plakun*, General Precision Laboratory Inc., Pleasantville, N.Y.

Standards for a Strong America

Published (1954) by American Standards Assn., 70 E. 45 St., New York 17. 100 pp. 8½ × 11 in. Paper bound. Price $3.00.

After some rather extensive amenities relating to the presentations of awards and official addresses, this volume has some 30 papers of a wide range of subject matter and varied interest, among which are:

Modular Planning and the Manufacturer, by Charles W. Kraft

American Society of Safety Engineers and Safety Standardization, by Henry D. Duffus

American Safety Standards — Demonstration of Industrial Self-Government, by Arthur S. Johnson

Standards for the Conservation of Hearing in Industry, by Prof. Walter A. Rosenblith

(Under "International Standards and What They Mean to the American Electrical Industry" there are six papers.)

Recent Developments in American Surface Finish Standards, by Roy P. Trowbridge

What the Purchasing Agent Wants From the Engineer in Standardization, two papers, by Nelson J. Gibbins, and by William R. Murray

Evaluating the Results of a Quality Control System in the Plant, three papers, by L. Grant Hector, by Dr. Ellis R. Ott, and by Thomas A. Budne

On color television, there are two papers:

The National Television System Committee as an Example of Systems Engineering and Industrial Standards, by Knox McIlwain

Derivation of the FCC Color Television Standard, by J. W. Wentworth

And a final paper of note:

How a Publication Can Further the Standards Movement, by Frank J. Oliver.

Communications and Electronics is a new

George Eastman House of Photography has been touring the country in the form of a trailer exhibit. The George Eastman House is the world's most complete and authentic museum of motion-picture memorabilia, housing priceless relics of the early days of motion pictures: early cameras and projection equipment, posters, antique picture animating devices, interesting still photographs from the first film shown commercially and other collector's items.

The especially designed trailer, under the sponsorship of Loew's Theatres Golden Jubilee, has been engineered to allow operation of some of the exhibits by visitors. It has a built-in generator to provide current for lighting and mechanization of the interior, and all displays have title cards explaining their origin and uses. Included in the mechanical portion of the museum exhibit is an early Edison projector and an original Lumière projector.

The historic advance of the motion picture over the past 50 years is graphically illustrated in a special display of valuable photographs and color transparencies. These show scenes from important early movies, and depict some of filmdom's immortal entertainment personalities.

Also on view is the world's first movie lithograph, fore-runner of today's advertising posters, a 1913 newsreel camera and an antique color camera. A complete projector of the same period is another interesting feature. Visitors to the George Eastman House trailer museum are invited to work an actual Mutoscope, the kind of peepshow movie that doubtless delighted their grandparents.

The Museumobile has already visited New York City, Cleveland, Akron, Canton, Indianapolis, Evansville, St. Louis, Toledo and Dayton. It is currently visiting New England cities in which Loew's Theatres are located.

The mobile exhibit was created by Gen. Oscar N. Solbert, director of the Rochester institution, and his curatorial staff. The objective is to give people all over the country a chance to see the priceless exhibits, since comparatively few people will be able to journey to Rochester for that purpose.

Membership Certificates (Active and Associate members only). Attractive hand-engrossed certificates, suitable for framing for display in offices or homes, may be obtained by writing to Society headquarters, at 55 West 42d St., New York 36. Price: $2.50.

Communications and Electronics is a new magazine published in England and concentrating on the uses to which new communication techniques and electronic devices can be put. Articles in the first issue, which appeared in September, included: communications and navigational aids in civil aviation; the applications of radio and allied techniques on British railways; colour television — present and future; transistors — a candid assessment; and automatic computation in research, industry and commerce. The magazine is published monthly, at $6 for twelve issues, by Heywood & Co. Ltd., Drury House, Russell St., Drury Lane, London W.C.2.

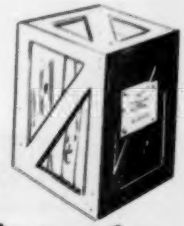
Armed Forces Institute of Pathology Three-Day Symposium

Held on January 17–19, with headquarters at Washington, this symposium of the Armed Forces Institute of Pathology centered about closed-circuit television and color television, ending with a three-city consultation by color television.

Early in the symposium, Ken Thomas, Head, TV Production Branch, Special Devices Center, Office of Naval Research, Port Washington, N.Y., spoke on "Closed-Circuit Television in Medical Education and Research," covering the basic principles of flexibility for originating equipment with the small, portable, vidicon camera chain as an example. To overcome the obstacle of using only one camera, the Special Devices Center has developed its Instructional TV System consisting of two image-orthicon cameras on two separate consoles on wheels. There is a master console and camera and a slave console and camera.

Dr. Alfred N. Goldsmith, pioneer electronics engineer and inventor, told how color television can now serve as a revolutionary tool for diagnosis, consultation, teaching and research in the fields of medicine and biology. He advised: "The system adopted for medical purposes should, to great advantage, be identical with the governmentally approved, simultaneous and compatible system now in vogue for broadcasting purposes. . . . If, on the other hand, color pictures of equal detail on an incompatible system were transmitted, the network coaxial cable or radio-relay connections would have to accommodate a frequency band of 8 to 10 mc width. This is two to three times as wide a band as is needed for compatible color-television signal transmission. Such a change would accordingly result in greater transmission costs and probably more limited availability of the corresponding special circuits and trained operating personnel qualified to handle them."

On the last day of the symposium, the cities of Baltimore and Washington were linked by closed circuit, by Radio Corporation of America, to Philadelphia where surgeons in an operating room of the University of Pennsylvania Hospital removed tissue from a patient for examination by a pathologist at Philadelphia and also by pathologists in Baltimore and Washington who saw microscopic views brought them by color television. An exchange of remarks about the diagnosis was made instantaneously.



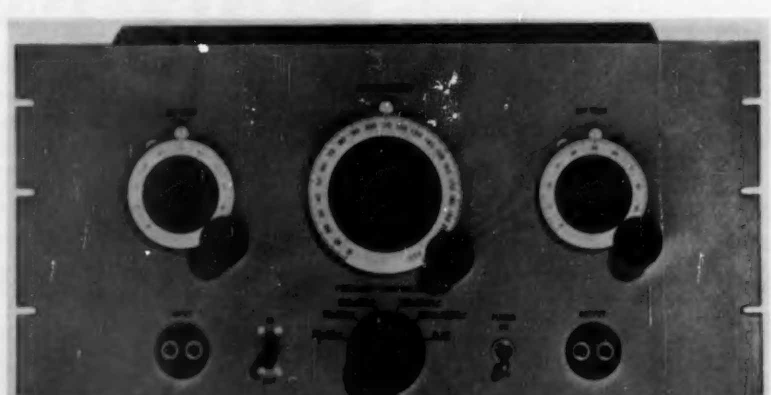
new products

(and developments)

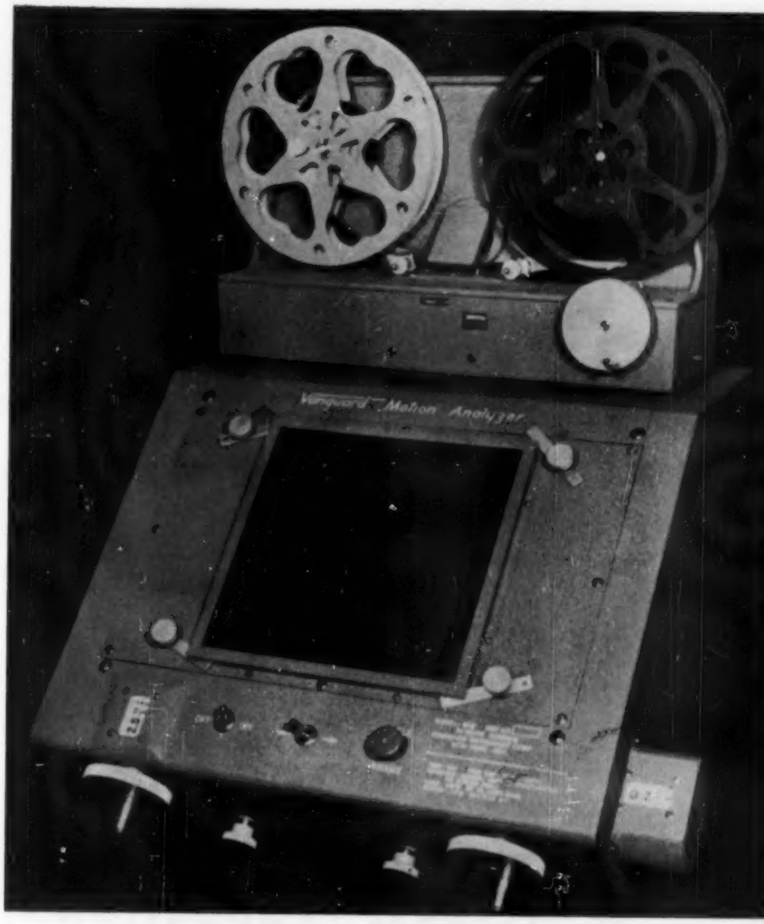
Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products or services.

The Magne-Cam System comprises a new line of three compact magnetic sound cameras originated by R. Rees Lumley, 339 South Warren St., Syracuse, N.Y. The Magne-Cam Jr. is a single system sound and picture camera to use prestriped, sensitized film of any type. It is driven by an a-c synchronous motor at 24 ft/sec only. Film capacity is 200 ft. Magne-Cam Sr. is also a single-system camera with demountable, light-trapped magazines of 200, 400 and 800-ft capacity. The recording amplifier is provided with a simple playback circuit for direct headphone monitoring. Magne-Cam Pro. uses the double system of recording sound magnetically. Picture and magnetic sound are recorded simultaneously on separate films, one conventional, the other a plain leader with a 100-mm magnetic stripe. Magazines are of 400, 800 and 1200-ft capacity. Other features are: dissolving shutter, Veeder counter, four-lens turret, direct playback, Wall D type intermittent. An accessory player and re-recorder, the Magne-Phone, is available.

A new variable high- and low-frequency filter for the elimination of unwanted noises in sound reproduction has been put into production by Cinema Engineering Co., Div. of Aerovox Corp., 100 Chestnut St., Burbank, Calif. Known as type 7052, it incorporates a 4-stage amplifier having an R-C interstage coupling network. Technical features include "in and out" switch, triple mu-metal shielding of transformers, shock mounting of tubes and general electrostatic and electromagnetic shielding to permit operation in low-level circuits. Frequency range is 20 to 15,000 cycles response, plus or minus 1 db. Output level is −2 dbm with output impedances to work into 200–250, 500–600 ohm balanced lines.



Processall is a new portable photographic film and paper processing unit designed to accept all conventional sizes of both roll films and papers up to a maximum of 12 in. wide, for automatic developing, fixing and drying. At present there are two basic models, with the smaller reported priced below $1,000. Full details are available from the Engineering Sales Dept., Oscar Fisher Co., Inc., 1000 N. Division St., Peekskill, N.Y. The unit is described as weighing less than 50 lb and 18 × 18 × 8 in. Motion-picture film in sizes 16mm, 35mm and 70mm is reported to be processed at 5 ft/min for black-and-white. Additional units may be added for color or reversal processing.



The Vanguard Motion Analyzer is a specialized projector which measures linear motion vs. the time interval of events recorded on film. Information thus obtained determines velocities, accelerations, deflections and stresses. The Analyzer is for use with 16mm film and has an image magnification of 10×; the lens is a 50mm $f/2.0$ Wollensak Raptar; film transport is either manual or motorized; counter both adds and subtracts; cross-hair positions can be read directly to 0.001 in. on dials; and projection head can be rotated 360° to align angular motions on film with either of two cross hairs. Although designed particularly to aid in the study of high-speed motion pictures, it can also be applied to oscilloscopic recordings on film, as well as to other photographic instrumentation. Sales agent is the Photographic Analysis Co., 100 Rock Hill Rd., Clifton, N.J. Price: $1825.00.

A new catalog of motion-picture printing equipment and accessories is available from Motion Picture Printing Equipment Co., 8136 North Lawndale Ave., Skokie, Ill. Detailed specifications and glossy photos are provided of this company's optical printers and printing heads, an automatic fade unit, electronic cuing system, and automatic light control shutter.

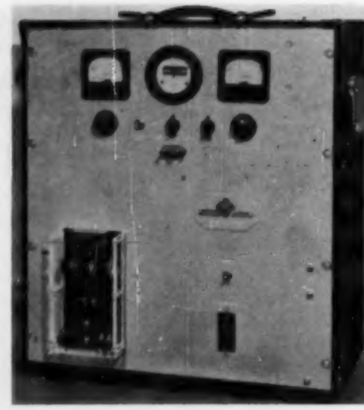
The Du Mont Color Planning Packet contains descriptive information on all Du Mont's color TV broadcasting equipment. Besides numerous leaflets on individual items, it includes a 35-page booklet showing complete planned systems and layouts and a 20-page brochure on the film multiscanner. Copies may be obtained from the Allen B. Du Mont Laboratories, Inc., Television Transmitter Dept., 1500 Main Ave., Clifton, N.J.

Professional Services

Byron, Inc., of Washington, D.C., announces the addition of a Magna-Striper unit to their laboratory. The Reeves machine is the 16mm counterpart of the same system that is used on CinemaScope productions. The system allows magnetic soundtrack to be added to any 16mm film, even films which already have an optical track. Narration, music, or special sound effects can then be added by the user as the film is projected. 100-mil track is used for regular sound stock, 50-mil track for a combination of magnetic and optical, and a 28-mil stripe is applied to the opposite edge for balancing. Byron, Inc. is prepared to offer one-day striping service to the trade. The price for any width is $1\frac{1}{4}$ cents per foot.

Kodak Books and Guides is a new listing of sources of information on all phases of photography, amateur and professional, published by the Eastman Kodak Co. The publications described in this guide have been prepared by experts in their respective photographic fields. They include the latest authoritative information on both general and specific photographic subjects, including the industrial, scientific and graphic arts fields. It is available, free of charge, from the Sales Service Div., Eastman Kodak Co., Rochester 4, N.Y.

The Siemens 16mm Recording Camera is a new camera which consecutively numbers each frame for time-lapse photography or synchronization of a number of cameras. It operates from a standard 24-v battery or rectifier and is capable of taking from 5 pictures a second to 1 picture an hour. Magazine-loaded, it permits 1600 individual exposures to be made in a single loading. Lenses up to 1000 mm (40 in.) are available. A Siemens Recording Camera Model B without lens, including power supply cable and focusing magnifier, costs \$395. Further information may be obtained from Ercona Camera Corp., 527 Fifth Ave., New York 17.



Variable-Frequency Input Power Supply Model V1B has been developed by Stancil-Hoffman Corp., 921 N. Highland Ave., Hollywood 38, Calif. It is designed to meet requirements of the instrumentation and recording fields. With the frequency source varying between 40 and 90 cycles and a voltage variation of from 100 to 150 v, the Model V1B will supply a 60-cycle frequency standard at 117 v under varying load conditions to a maximum of 500 w. In addition to the portable unit shown, it is also designed for rack or cabinet mounting. It is 21 × 19 × 10 in. and weighs 145 lb.

employment service

These notices are published for the service of the membership and the field. They are inserted three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Motion-Picture Engineer. Seeking position of responsibility and future in research, development and experimental field along the line of 35mm professional cinematography or related industry. Age 41, have 18 yr engineering experience with all types 35mm professional cameras and projectors, both domestic and foreign make. Excellent background in physics, optics, mechanical design and capability in conducting tests and experiments. Experience in preparation of descriptive technical literature and patent evaluation. Full details upon request to: P.O. Box 3102, Los Angeles 28.

Motion Picture Production. Desire position as cameraman. Seven years experience includes, as well as camera, some lab and editorial work. Full details given on request. Available after 15 April. Age 24 and single. Will locate anywhere. Write: Normal E. C. Naill, College Ave., New Windsor, Md.

Writer/Production Assistant. College grad with varied experience in TV film work wants affiliation with progressive firm. Strong commercial copy, dignified documentary, imaginative cartoon creations—all with cost-conscious approach. Staff or free-lance. Resume and samples on request. Len Pullen, Belle Mead, N.J.

Motion Picture Production. All-around small-studio man, experienced in 16mm and 35mm projection, at present studying all phases of cinematography at U.S.C. Los Angeles area only. Joseph Schneider, 1255 N. Sycamore Ave., Hollywood 38. Tel: Hollywood 7-2859.

Positions Available

Technical Director. Due to plans for expansion, we invite applications from qualified technical administrators capable of directing, supervising and coordinating technical departments. Qualifications are overall knowledge of modern color photographic processes, both still and motion-picture, including supervisory experience in photographic chemistry, sensitometry, quality control and research. We require a man of sufficient stature and ability ultimately to assume responsibility for these departments and coordinate their efforts with production and sales requirements. Salary open. Address application to: Leo Pavelle, President, Pavelle Color Inc., 533 West 57 St., New York 19.

B.S. or M.S. Chemical Engineer wanted for training in photographic processing technology, leading to staff position under Process Supervisor. Ultimate duties will include setting up and maintenance of processing tolerances, trouble shooting on technical problems, supervision of new processes during initial production phases. Shift work. Send brief resume including approximate salary requirements to E. E. Griffith, Technicolor Motion Picture Corp., 6311 Romaine St., Hollywood, Calif.

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Journals Available and Wanted

These notices are published as a service to expedite disposal and acquisition of out-of-print Journals. Please write direct to the persons and addresses listed

Available

Dec., 1936; Jan., Feb., Apr., May, July, Sept., Nov. 1937; 1938 complete; 1939 complete; 1940 complete; Jan.–Aug. 1941. Write Richard S. Norton, Warner News Inc., 625 Madison Ave., New York 22.

Collection of back issues available either singly or as a lot. Write F. H. Cole, 1258 So. Burnside Ave., Los Angeles 19.

Wanted

Complete set of Transactions. Write John Flory, Eastman Kodak Co., 343 State St., Rochester 4, N. Y.

High-Speed Photography, Volumes 1, 2 and 3. Write Jack Gershon, Armour Research Foundation, Technology Center, Chicago 16.

Transactions Nos. 6 and 9. Write W. W. Hennessy, 503 West 41 St., New York.

Signal Corps Pictorial Center could use a complete set of Journals, preferably as a donation. Write John P. Byrne, Motion Picture Sensitometrics, Signal Corps Pictorial Center, 45-15 48 St., Long Island City 4, N. Y.

Transactions Nos. 1, 5, 6, 7 and 9. Write Lloyd E. Varden, Pavelle Color Inc., 533 West 57 St., New York 19.

Meeting Calendar

SMPTE Central Section, Feb. 21, Mar. 17, May 16, June 13.
Institute of Radio Engineers, National Convention, Mar. 21–24, Kingsbridge Armory, Bronx, N.Y.
Inter-Society Color Council, Apr. 6, Hotel Statler, New York.
Optical Society of America, Apr. 7–9, Hotel Statler, New York.
77th Semiannual Convention of the SMPTE, Apr. 18–22, Drake Hotel, Chicago.
National Academy of Sciences, Apr. 25–27, Washington, D.C.
American Physical Society, Apr. 28–30, Washington, D.C.
International Commission on Illumination, June 13–22, Zürich, Switzerland.
International Aeronautical Conference, joint mtg. of the British Aeronautical Society and the Institute of the Aeronautical Sciences, June 21–24, Los Angeles.
American Institute of Electrical Engineers, Summer General Meeting, June 27–July 1, New Ocean House, Swampscott, Mass.
Biological Photographic Association, Annual Meeting, Aug. 30–Sept. 2, Wisconsin Hotel, Milwaukee.
Illuminating Engineering Society, Sept. 12–16, Cleveland, Ohio
78th Semiannual Convention of the SMPTE, Oct. 3–7, Lake Placid Club, Essex County, N.Y.
American Institute of Electrical Engineers, Fall General Meeting, Oct. 3–7, Morrison Hotel, Chicago.
Photographic Society of America, Annual Convention, Oct. 5–8, Sheraton-Plaza Hotel, Boston, Mass.
Audio Engineering Society, Oct. 13–16, New York.
American Standards Association, 37th Annual Meeting and Sixth Annual Conference on Standards, Oct. 24–26, Washington, D.C.
79th Semiannual Convention of the SMPTE, Apr. 29–May 4, 1956, Hotel Statler, New York.
80th Semiannual Convention of the SMPTE, Oct. 7–12, 1956, Ambassador Hotel, Los Angeles.
81st Semiannual Convention of the SMPTE, Apr. 28–May 3, 1957, Shoreham Hotel, Washington, D.C.
82d Semiannual Convention of the SMPTE, Oct. 6–11, 1957, Hotel Statler, New York.

SMPTE Officers and Committees: The rosters of the Officers of the Society, its Sections, Subsections and Chapters, and of the Committee Chairmen and Members were published in the April Journal.

sustaining members

of the Society of Motion Picture and Television Engineers

Alexander Film Co.
Altec Companies
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Bijou Amusement Company
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- The Hertner Electric Company
- International Projector Corporation
- J. E. McAuley Mfg. Co.
- National Theatre Supply
- The Strong Electric Company

W. J. German, Inc.
Guffanti Film Laboratories, Inc.
The Houston Fearless Corporation
Hunt's Theatres
Hurley Screen Company, Inc.
The Jam Handy Organization, Inc.
Kollmorgen Optical Corporation
Lorraine Carbons
Major Film Laboratories Corporation
J. A. Maurer, Inc.
Mecca Film Laboratories, Inc.
Mitchell Camera Corporation
Mole-Richardson Co.
Motiograph, Inc.
Motion Picture Association of America, Inc.
- Allied Artists Productions, Inc.
- Columbia Pictures Corporation
- Loew's Inc.
- Paramount Pictures Corporation
- Republic Pictures Corp.
- RKO Radio Pictures, Inc.
- Twentieth Century-Fox Film Corp.
- Universal Pictures Company, Inc.
- Warner Bros. Pictures, Inc.

Motion Picture Printing Equipment Co.
Movielab Film Laboratories, Inc.
National Carbon Company
- A Division of Union Carbide and Carbon Corporation

National Cine Equipment, Inc.
National Screen Service Corporation
National Theaters Amusement Co., Inc.
Neighborhood Theatre, Inc.
Neumade Products Corp.
Northwest Sound Service, Inc.
Pathé Laboratories, Inc.
Polaroid Corporation
Producers Service Co.
Projection Optics Co., Inc.
Radiant Manufacturing Corporation
Radio Corporation of America, Engineering Products Division
Reid H. Ray Film Industries, Inc.
Raytone Screen Corp.
Reeves Sound Studios, Inc.
S.O.S. Cinema Supply Corp.
SRT Television Studios
Shelly Films Limited (Canada)
The Stancil-Hoffman Corporation
Technicolor Motion Picture Corporation
Terrytoons, Inc.
Titra Film Laboratories, Inc.
United Amusement Corporation, Limited
Wenzel Projector Company
Westinghouse Electric Corporation
Westrex Corporation
Wilding Picture Productions, Inc.
Wollensak Optical Company